THE CULTURE AND DISEASES OF THE ONION

TAUBENHAUS AND MALLY

THE
CULTURE AND DISEASES OF THE ONION

BY J. J. TAUBENHAUS

THE CULTURE AND DISEASES OF THE SWEET PEA.

DISEASES OF TRUCK CROPS AND THEIR CONTROL.

DISEASES OF GREENHOUSE CROPS AND THEIR CONTROL.

THE CULTURE AND DISEASES OF THE SWEET POTATO.

Each Fully Illustrated

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THE CULTURE AND DISEASES OF THE ONION

BY

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TO

ALL WHO CONSTANTLY STRIVE AND WORK
FOR A BETTER UNDERSTANDING
OF MAN BY MAN
THIS BOOK IS DEDICATED

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INTRODUCTION

The onion is one of the most important truck crops in the United States. It ranks third in importance among all the vegetables grown in this country. There is probably not a home, whether among the prosperous, or among the poorest classes, where the onion does not find its place, more or less constantly, in the diet. It is prepared for food in almost every conceivable manner, whether raw or cooked. There are very few home gardens where the onion patch is not given a prominent place. The United States Department of Agriculture has estimated that in 1920 the total production of the onion crop was 12,651,704 bushels, valued on the farm at $16,706,826.

There are no crops, whether grown intensively, or extensively, which are not subject to heavy annual tolls through the ravages either of plant diseases or insect pests. It has been conservatively estimated that the losses from onion diseases of growing crops in the United States amounted to 15 per cent of the 1920 production. The amount of this loss was approximately $2,506,023. It has been further estimated that there was another 10 per cent loss due to diseases of onions developed in transit or in storage. Including this loss, the total amount of damage to the 1920 production aggregated about $4,176,705.

The losses from the ravages of insect pests also total astonishing amounts. Hence it must be evident that, if the losses from insect pests and plant diseases attacking this crop can be prevented, either wholly or in part, the authors would be justified in their attempts to make this information available to the producers in a concise and practical form. It is hoped that the data submitted in this guide may enable the growers to reduce their losses from insect pests and diseases to a minimum.

The senior writer is responsible for the presentation of the text dealing with the diseases, while both writes assume responsibility for the preparation of the text on the culture of the onion and insect pests. Both authors are fully aware that it is not possible to submit complete detailed discussions of all varieties, all methods of culture, in all localities, in so brief a textbook as the present volume. It is not intended that it should be an exhaustive monograph, but only a concise, practical summary of the important information which will be of assistance to the average grower. The book is also designed to become useful as a reference for students, teachers, and investigators in horticultural crops.

Considerable space is devoted to the cultural methods of Bermuda onions as grown in the southern states under irrigation. Generally speaking, the truck growers who produce their crops under a system of irrigation usually apply intensive methods. Any fairly complete discussion of the culture of this crop under irrigation will be of immense value to the growers of the crop under any other system, provided they intelligently adapt the fundamentals of the suggestions made, or methods given, to their particular locality. Serious errors in the adaptation of methods have been guarded against by giving a brief outline of the cultural methods of growers of American varieties of onions in the onion-growing states of the east, north and west.

In the second part of this book, the diseases of the onion have not been arranged in order of economic importance but rather according to systematic mycological classification. The writers wish to acknowledge their indebtedness to the Plant Disease Survey of the U. S. Dept. of Agr. for data furnished on distribution of onion diseases in the United States, to the U. S. Bureau of Markets and Crop Estimates for data contained in Tables 1 to 6, to Dr. W. A. Orton, U. S. Dept. of Agr., for data contained in Table 17. Heartfelt thanks are also due to the Plant Pathologists of the various Experiment Stations for their kindness in furnishing illustrations of various onion diseases and for which due credit is acknowledged in the proper place. Likewise, and whenever illustrations were borrowed from station bulletins, or other sources, due mention is made of this fact. Many of the photos showing cultural operations were made by the junior writer. The illustrations in Fig. 12, on pink root of onions, were borrowed from Texas Station Bul. 273, which were originally taken for the Division of Plant Pathology by the Station photographer. The writers wish also to express their indebtedness to Professor W. H. Thomas, professor of English, A. & M. College of Texas, for assistance in reading the manuscript, to Miss Stella Stuart, secretary, for assistance in preparing the index, and to Miss Elizabeth Wood, laboratory assistant, for help in reading the galley proofs.

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College Station, Texas,
January 15, 1923.

CONTENTS

PART I

CULTURE

CHAPTER I PAGE

HISTORICAL — WORLD DISTRIBUTION — GEOGRAPHIC DISTRIBUTION IN THE UNITED STATES — CLIMATIC REQUIREMENTS — ECONOMIC IMPORTANCE.......... 3

CHAPTER II

VARIETIES — SOIL REQUIREMENTS — SELECTION OF LOCATION.......... 16

CHAPTER III

SOIL PREPARATION — HARD PAN, PLOW SOLE, AND DEEP TILLAGE — LEVELING THE LAND TO A UNIFORM GRADE — DETERMINING THE GRADES, MAKING THE DITCHES AND BORDERS — BORDER ROWS, FURROWS, OR BEDS — BEDDED ROWS, FURROW IRRIGATION AND HORSE CULTIVATION — THE TWO ROW BED SYSTEM, WITH FURROW IRRIGATION AND HORSE CULTIVATION — THE FLAT BED AND BORDER SYSTEM.......... 23

CHAPTER IV PAGE

Use of Fertilizers — Application of Farm Manures — Use of Cover Crops — Commercial Fertilizer — Use of Lime — Use of Phosphate — Use of Potash — Use of Nitrate of Soda — Use of Sulphate of Ammonia — Bat Guano — Use of Cotton Seed Meal — Tankage — Fertilizing Virgin Soils — Fertilizing Old Lands — Crop Rotation..... 33

CHAPTER V

Seed Testing — Bermuda Onion Seed — Methods of Laying Off Seed Beds —Preparation of the Seed Bed — Time of Sowing — Amount of Seed for Sowing — Depth of Sowing Seed — Cultivation of the Seed Bed — Advantages of Transplanting — Transplanting — Root System of the Bermuda Onion.................................. 47

CHAPTER VI

Irrigation — Amount of Irrigation Water — Overhead System of Irrigation.......... 59

CHAPTER VII

Cultivation — Horse Cultivation — Onion Culture under Dry Farming — Producing a Crop of Bermudas Direct from Seed — Propagation of Onions from Seed Versus Green Sets — The Use of Dry Sets — Green Bunching Onions — Frost Warnings....... 64

CHAPTER VIII PAGE

HARVESTING AND CURING — METHOD OF HARVESTING — SHUFFLING, CLEANING, AND CRATING 77

CHAPTER IX

GRADING — CONTAINERS — MARKETS AND MARKETING — LOADING THE CARS — REFRIGERATOR CARS.............................. 85

CHAPTER X

THE DRY KILN, THE DEHYDRATOR, AND DRIED ONIONS — STORAGE — COST OF PRODUCTION — TOOLS AND IMPLEMENTS..................... 97

CHAPTER XI

HOME PRODUCTION OF ONION SEED — SELECTION AND CARE OF THE BULBS — PRODUCTION OF SEED FOR ONION SET GROWING — CARE OF ONION SEED.............................. 105

PART II

DISEASES

CHAPTER XII

TROUBLES NOT DUE TO PARASITES — BASTARD BLOSSOM — BULBLET HEAD — DOUBLE FLOWER HEAD — ELONGATED SPATHE — GOOSENECK — HAIL INJURY — WHITE RING — ONION BRITTLE — FALSE BLIGHT — WHITE SPOT............ 115

CHAPTER XIII PAGE
SOFT ROT — DOWNY MILDEW................ 119

CHAPTER XIV
SMUDGE (BLACK SPOT, OR ANTHRACNOSE)....... 131

CHAPTER XV
SMUT................................. 136

CHAPTER XVI
RUST — WATERY SOFT ROT — BLACK MOLD.. 164

CHAPTER XVII
NECK ROT — LEAF MOLD.................. 169

CHAPTER XVIII
PINK ROOT — FUSARIUM ROT................ 179

CHAPTER XIX
WHITE MOLD — FUNGI PARASITIC ON MEMBERS OF THE GENUS ALLIUM — DODDER INJURY..... 201

CHAPTER XX
STORAGE ROTS — DISEASES PRIMARILY IMPORTANT IN TRANSIT........................... 208

CHAPTER XXI
ANIMAL OR INSECT PESTS — ROOT KNOT — THRIPS — CONTROL METHODS — ONION MAGGOTS — CUT WORMS — WIRE WORMS........ 223

LIST OF ILLUSTRATIONS

FIGURE		FACING PAGE
1.	Cultivation and Irrigation	26
2.	Making Borders, Irrigation, and Spraying	31
3.	Dipping Tank, Containers, Graders	85
4.	Curing Sheds, Storage Houses, Stages in Seed Production	99
5.	Troubles Not Due to Parasites	115
6.	Bacterial Soft Rot and Downy Mildew	121
7.	White Mold and Anthracnose	134
8.	Onion Smut	141
9.	Onion Smut	161
10.	Black Mold, Root Knot, and Splitting of Bulbs	166
11.	Neck Rot	170
12.	Pink Root	193
13.	Insect Injury	226

Part I

CULTURE

Part I

CULTURE

CHAPTER I

Historical

The onion belongs to the family *Liliaceæ* and the widely variable species *Allium cepa.* One peculiarity of this family is that most of its plants will grow in soil containing an abundance of moisture, and they also withstand some salts or alkali. The onion is commercially grown for the use of its bulb, although frequently its leaves are also employed for seasoning and are consumed in various ways.

The onion is perhaps one of the oldest of our cultivated crops, although, strange as it appears, its original home has not been exactly established. It is very probable that it is a native of Southern Asia. It was well known to many of the early travelers, as it was extensively used by them as a food to prevent thirst when passing through a desert. It was no doubt introduced into the United States with the early settlers, as it is doubtful whether the aboriginal Indians ever knew of it before. There seems to be no authentic information as to when the onion was first introduced into the various states where it is now grown extensively. In Texas, T. C. Nye, of Cotulla, La Salle County, was perhaps the first to raise Bermuda onions for shipment. These were consigned to the markets of Milwaukee, Wisconsin. They carried through in splendid condition. Because of his first success, Mr. Nye increased the acreage and encouraged others to go into the growing of this crop. He was instrumental in starting the Bermuda onion industry, both in the Cotulla and the Laredo districts.

World Distribution

Unlike many other crops, the onion will thrive under a wide range of climate and soil. It is well adapted to the valley of the Nile river in Egypt, to the volcanic soils of the tropics, and the South Sea Islands. It likewise thrives well in irrigated portions of arid and semi-arid regions. It is merely a question of type and variety for each territory.

Geographic Distribution in the United States

In the United States the onion will grow everywhere except in the most mountainous regions. It is grown in practically every state of the Union. The Laredo district in Webb County alone produces on an average about 35 per cent of the entire Texas Bermuda onion crop; Dimmit County about 30 per cent; Zavala, La Salle, Frio, Nueces, and Atascosa 20 per cent. In all these counties maturity is slightly later than at Webb County, Texas. Hidalgo and Cameron counties produce approximately 10 per cent, and the remaining 5 per cent grown in Texas is produced in the scattering counties of Maverick, Medina, Brooks, Wilson, Karnes, and Jim Wells. A few cars of Bermuda onions are usually produced each year in the counties of Bexar, Comal, Guadalupe, Kleberg, Hays, Bee, San Patricio, De Witt, Austin, Lavaca and Fayette.

East Texas tomato growers have tested the Bermuda onion in their respective localities. They secure plants from the seed beds of the Laredo growers and transplant in March. Experience there has shown that the Bermuda onion may be successfully grown in eastern Texas for home use and local markets.

The bulk of the Bermuda onion crop is now, and probably ever will be, grown in southern Texas under some system of irrigation. The counties of Webb, Maverick, Hidalgo, and Cameron secure irrigation waters almost exclusively from the Rio Grande River. Dimmit, Zavala, and La Salle counties irrigate from both artesian wells and the Nueces River; in Frio and Atascosa counties and the northeastern portion of La Salle County the growers irrigate from artesian wells and the Frio River. The Nueces County crops are grown in three-foot rows, usually without irrigation.

The Lafourche Parish, Louisiana district, began growing a few commercial crops of Bermuda onions about 1910. Since then the industry has gradually increased to 300 to 500 acres annually.

The Coachella Valley, California district, began producing commercial crops of Bermuda onions about 1915. Soon after the growers of the Imperial Valley began producing Bermuda onions. The industry advanced rapidly in California, until 2000 to 3000 acres are annually devoted to this crop. The further distribution of the onion in states where the northern varieties are grown is shown in Table 1.

CLIMATIC REQUIREMENTS

Onions will grow under the widest range of climatic conditions. However, where the best results are to be obtained, a temperate climate without extremes of heat or cold is ideal for this crop. Onion culture will seldom be profitable in regions without definite seasons of heat, cold, rainfall or drought. A mild climate with plenty of moisture during the early stages of growth, and a reasonable degree of heat, together with dryness of both soil and atmosphere during the ripening season, constitutes an ideal climate for this crop. In the southern part of the United States, to which region onions are well adapted, the growing season begins during the late autumn and winter months, and the crop matures during the spring and the early summer. If the crop matures when there is considerable rainfall, it will be practically impossible to cure the bulbs, and they will as a result stand shipment very poorly. There are certain types, such as "top onions" and multipliers or "potato onions," which are very hardy and well adapted to the northern as well as southern states. These types, however, are not suited for market purposes as dry onions. They are produced and marketed as green onions, known as "peelers" or "bunches." Likewise, among the commercial types of onions, there exists a marked difference as to hardiness, so that some varieties are best adapted to northern states, while others, like the Bermuda, the Egyptian, and the Spanish types, thrive best in restricted southern localities.

In South Texas, for instance, where the climate is mild and dry during the winter and hot and dry during the early spring and summer, conditions are best suited

TABLE I

Acreage, Yield, Production, Price, and Farm Value of Commercial Crop in 1921

States	Acreage	Yield per Acre	Production (Bushels)	Price per Bushel	Total Value
BERMUDA AND CREOLE CROP					
California	2,000	245	490,000	$1.28	$627,200
Louisiana	1,010	206	208,060	.95	197,657
Texas	10,503	207	2,174,121	.83	1,804,520
Total	13,513		2,872,181		$2,629,377
INTERMEDIATE CROP					
Iowa	1,250	202	252,500	$1.20	$303,000
Kentucky	1,000	175	175,000	.70	122,500
Maryland	300	250	75,000	1.20	90,000
New Jersey	2,380	239	568,820	1.15	654,143
Texas	800	275	220,000	.86	189,200
Virginia	820	280	229,600	1.13	259,448
Washington	789	271	213,819	1.41	301,485
Total	7,339		1,734,739		$1,919,776
LATE CROP					
California	7,149	225	1,608,525	$1.40	$2,251,935
Colorado	765	250	191,250	1.53	292,612
Idaho	145	570	82,650	1.00	82,650
Illinois	1,052	210	220,920	1.28	282,778
Indiana	3,931	237	931,647	1.32	1,229,774
Massachusetts	4,500	260	1,170,000	1.77	2,070,900
Michigan	1,275	225	286,875	1.65	473,344
Minnesota	1,280	122	156,160	1.27	198,323
New York	7,255	268	1,944,340	1.60	3,110,944
Ohio	5,593	191	1,068,263	1.53	1,634,442
Oregon	609	296	180,264	1.07	192,882
Pennsylvania	289	200	57,800	1.51	87,278
Utah	124	250	31,000	2.45	75,950
Wisconsin	1,010	114	115,140	1.51	173,861
Total	34,977		8,044,834		$12,157,673
United States	55,829		12,651,754		$16,706,826

for the Bermuda type. Under these conditions, the mild climate makes it possible to grow the Bermuda onion as a winter crop. There, too, the dry, hot spells early in the spring assist in the early maturity of that crop. If the spring is cool and late, the Bermuda onion will not ripen properly; hence it ships poorly. Generally speaking, it requires a period of about 150 days for the Bermuda onion to make a crop if it is grown from seed. If sets are used, the crop will often make and mature in 100 days. The northern varieties are well adapted to those states where the onion crop is grown principally during the summer months.

ECONOMIC IMPORTANCE

In the United States the onion ranks third among the truck crops grown. In 1908 about 14,000,000 bushels were produced and valued at $10,000,000, all of which were practically consumed in the States. In addition to this, we annually import nearly 1,500,000 bushels of onions from Spain, Egypt, and the South Sea Islands and Bermuda. There is hardly a home-vegetable garden that is without its onion patch. Likewise, it requires moderate capital to grow onions on a large scale for the market. Contrary to many other truck crops, the demand for the onion extends throughout the entire year. In addition to the market types of onions, truckers have developed a regular industry in growing various types of Spanish and Bermuda onions in the Gulf Coast states.

Recent figures by the Bureau of Markets and Crop Estimates show that the production of onions in the United States in 1921 has been 12,651,754 bushels, valued at $16,706,826. If these figures are compared to those of the production of 1908, it will be seen that during 1921 there were produced about 2,000,000 bushels less, but the total value of the crop was estimated at $6,000,000 more than that of 1908. There seems no doubt that the reduction in output was due largely to certain diseases which restrict the culture of onions considerably. Table 1 shows the production by states of the onion crop as it was grown during 1921 for early, intermediate, or late markets.

In 1915 Texas alone produced 2,300,000 bushels, valued at $2,500,000. The returns to the growers were about $1,500,000, with one-fifth of that off for crates. The year 1915, however, was one of low prices. The Texas, Bermuda onion crop usually begins reaching the market from about the end of March and continues to the first or the middle of June. This means that the Texas onion growers have but two months in which to harvest and market their product. Since the northern onions usually hold over until the April market, the Texas growers have not, as yet, been able to dispose profitably of an average of more than 4000 to 5000 cars per year.

In estimating the economic value of the onion crop in the United States, we should remember that a certain amount of it as it is grown in the various states is consumed locally. We should bear this in mind when comparing the number of carlot shipments during any one year. Tables 2 to 6 indicate the carlot shipments of onions during the calendar years of 1917 to 1921 inclusive. These figures were prepared for the authors by the Division of Markets and Crop Estimates of the United States Department of Agriculture. In studying these tables, one sees that in 1917 about 19,152 cars were shipped by various onion growers to the markets

TABLE 2

Carlot Shipments of Onions, Calendar Year 1917

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
Arkansas	...	...	...	...	...	...	...	1	...	...	...	...	1
California	45	30	53	4	371	402	170	320	631	837	310	84	3,257
Colorado	4	...	...	...	...	...	...	...	31	109	38	3	185
Idaho	2	...	...	...	...	...	...	...	...	19	15	11	47
Illinois	...	...	...	...	...	...	3	35	30	82	11	3	164
Indiana	63	21	3	2	5	...	...	8	179	348	178	74	881
Iowa	...	...	...	...	...	...	7	211	143	279	36	...	676
Kansas	...	...	...	...	...	...	...	...	...	...	2	...	2
Kentucky	13	12	1	...	...	...	92	39	12	14	2	...	185
Louisiana	...	...	...	3	122	36	11	1	...	...	...	1	174
Maryland	4	3	...	1	...	...	3	7	...	...	...	...	18
Massachusetts	202	66	29	1	...	...	9	143	717	822	191	115	2, 295
Michigan	8	2	1	...	...	...	...	...	10	49	42	9	121
Minnesota	3	1	...	...	1	...	...	1	65	418	41	15	545
Missouri	...	...	...	...	...	...	...	1	1	5	1	...	8
Montana	...	...	...	...	...	...	...	...	...	1	3	...	4
Nebraska	...	...	...	...	...	...	...	...	...	8	1	...	9
Nevada	1	...	...	...	...	...	...	...	...	...	...	...	1
New Hampshire	...	...	...	...	...	...	...	...	...	...	...	2	2
New Jersey	...	...	...	...	...	5	215	192	116	26	5	2	561
New York	74	27	33	15	...	...	3	159	436	501	218	91	1,557
North Dakota	...	...	...	...	...	...	...	...	5	9	...	...	14
Ohio	498	181	96	12	...	...	...	29	300	341	156	51	1,664
Oregon	66	12	12	...	2	...	1	4	3	42	40	25	207
Pennsylvania	...	...	...	...	...	...	...	7	22	13	15	3	40
Texas	...	...	3	2641	2459	713	32	31	17	...	...	...	5,896
Utah	...	...	...	...	...	...	...	...	...	22	4	1	27
Virginia	...	...	...	...	...	...	87	56	1	4	4	1	153
Washington	3	...	1	...	...	...	45	189	27	26	13	4	308
Wisconsin	...	...	...	...	...	...	...	...	14	93	22	21	150
Total	986	355	232	2679	2960	1156	678	1434	2740	4068	1348	516	19,152

TABLE 3

Carlot Shipment of Onions, Calendar Year 1918

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
Alabama	...	...	...	...	...	3	...	...	...	...	...	...	3
California	181	98	55	42	355	529	268	476	690	726	454	134	4,008
Colorado	17	8	18	12	3	...	...	...	12	64	44	20	198
Connecticut	...	...	1	...	...	...	...	...	...	...	...	...	1
Florida	...	...	1	3	21	...	...	...	...	...	...	...	25
Idaho	12	6	8	...	...	...	...	...	...	1	1	...	28
Illinois	6	34	22	4	...	...	7	54	44	87	25	22	305
Indiana	144	155	82	33	3	...	1	86	465	494	257	109	1,829
Iowa	4	15	8	5	...	...	87	316	144	251	96	45	971
Kansas	...	...	...	...	...	...	...	...	1	...	...	...	1
Kentucky	6	2	10	...	...	46	140	7	2	...	...	...	213
Louisiana	...	...	...	2	55	117	68	54	59	67	15	13	450
Maryland	...	...	...	1	...	...	...	...	...	...	...	...	1
Massachusetts	151	225	254	127	12	...	20	87	576	1124	199	87	2,862
Michigan	12	45	66	17	3	...	...	3	57	110	206	71	590
Minnesota	16	38	22	8	2	...	...	3	97	297	266	83	832
Mississippi	...	...	...	...	1	...	...	...	...	...	...	...	1
Missouri	2	3	1	...	...	...	3	...	...	1	...	...	10
Montana	...	1	...	...	...	...	...	...	...	...	...	...	1
Nebraska	...	...	...	...	...	...	...	1	...	1	...	...	2
Nevada	...	...	2	...	1	...	...	...	...	...	...	...	3
New Hampshire	...	...	...	...	...	...	...	...	...	1	9	...	10
New Jersey	1	1	2	2	...	55	246	137	80	50	21	2	597
New York	156	184	223	115	18	...	13	333	489	396	481	213	2,621
Ohio	145	170	205	64	12	2	2	102	262	411	264	166	1,805
Oregon	25	30	13	6	7	...	1	...	8	15	14	19	138
Pennsylvania	...	6	7	1	1	...	6	6	2	21	19	8	77
South Dakota	...	...	...	...	...	...	...	...	...	...	1	...	1
Texas	...	...	...	1344	1789	373	57	10	2	...	...	...	3,575
Utah	...	...	...	...	...	...	...	...	...	...	1	...	1
Virginia	2	...	3	...	1	16	74	3	...	...	...	...	99
Washington	6	3	...	1	1	...	184	243	20	6	3	...	467
Wisconsin	15	38	20	12	5	...	...	...	65	88	34	25	302
Total	901	1062	1023	1799	2290	1141	1177	1921	3075	4211	2410	1017	22,027

TABLE 4

Carlot Shipments of Onions, Calendar Year 1919

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
Arizona	...	...	...	...	1	...	...	...	...	...	...	...	1
California	105	104	125	59	481	323	473	641	1421	1008	340	139	5,219
Colorado	47	23	19	1	...	...	...	...	24	46	21	17	198
Idaho	5	1	2	...	...	...	...	...	7	5	...	...	20
Illinois	48	29	14	2	1	1	8	13	35	34	5	5	195
Indiana	204	130	64	7	...	...	9	121	253	148	133	89	1,158
Iowa	14	4	9	2	...	...	115	161	78	75	37	7	502
Kansas	...	...	...	...	...	...	3	2	1	...	...	...	6
Kentucky	...	...	...	...	...	48	287	3	1	...	...	...	339
Louisiana	...	...	...	1	58	42	...	...	...	...	...	...	101
Maryland	...	...	...	...	...	2	26	11	...	...	...	...	39
Massachusetts	244	260	207	78	1	...	92	202	719	615	289	210	2,917
Michigan	52	53	31	7	...	...	...	3	19	45	60	38	308
Minnesota	51	15	8	2	...	...	...	16	215	147	21	14	489
Mississippi	...	...	...	...	1	...	...	...	...	...	...	...	1
Missouri	...	...	...	2	...	...	24	...	1	...	...	...	27
Nebraska	...	...	...	...	...	...	...	...	2	1	...	...	3
Nevada	...	4	2	...	...	...	...	...	1	...	...	...	7
New Jersey	1	1	3	1	...	84	355	70	71	27	22	3	638
New Mexico	1	...	...	...	...	...	...	...	...	...	...	...	1
New York	288	215	192	156	8	...	54	227	277	413	504	254	2,588
North Dakota	2	1	...	...	...	...	...	...	1	...	...	...	4
Ohio	337	281	168	15	...	...	28	77	323	267	206	188	1,890
Oklahoma	...	...	...	...	...	...	1	...	...	...	...	...	1
Oregon	32	48	76	22	3	...	...	2	7	64	40	16	310
Pennsylvania	6	7	4	...	...	...	25	30	7	26	12	1	118
Rhode Island	1	...	...	...	...	...	...	...	...	...	...	...	1
Texas	...	...	...	828	1907	101	7	32	1	...	...	...	2,876
Utah	...	...	...	...	...	...	...	...	3	12	2	...	17
Virginia	1	...	...	...	...	45	88	...	...	...	...	...	134
Washington	5	9	6	...	1	...	249	297	26	14	3	1	611
Wisconsin	44	28	19	6	...	...	...	1	29	16	7	5	155
Total	1488	1213	949	1189	2462	646	1844	1909	3522	2963	1702	987	20,874

TABLE 5

Carlot Shipments of Onions, Calendar Year 1920

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
California......	211	208	143	86	1088	358	222	283	753	783	272	119	4,526
Colorado.......	49	38	12	...	...	...	...	...	5	51	12	10	177
Delaware.......	...	...	...	...	...	...	...	1	1	...	...	...	2
Florida.........	...	...	...	17	10	...	...	...	...	...	...	...	27
Idaho..........	...	1	...	...	...	...	...	...	1	16	9	1	28
Illinois.........	6	5	5	7	...	...	1	26	33	176	37	4	300
Indiana........	121	100	31	...	...	...	...	78	669	80	560	217	2,646
Iowa...........	11	1	3	...	...	...	14	279	224	153	121	18	824
Kansas.........	...	...	...	...	...	...	...	2	2	...	1	...	5
Kentucky......	...	...	...	...	...	...	204	76	15	3	1	...	299
Louisiana.......	...	...	...	...	46	41	8	9	2	...	...	...	106
Maine..........	...	1	...	...	...	...	...	...	...	...	...	...	1
Maryland......	...	...	...	...	...	...	7	50	30	2	...	...	89
Massachusetts...	242	200	223	43	...	...	3	189	619	1025	644	185	3,373
Michigan.......	7	27	25	...	...	...	...	1	77	184	138	117	576
Minnesota......	16	7	3	...	...	...	...	...	25	109	70	2	232
Missouri.......	...	...	...	...	...	...	3	1	...	...	...	...	4
Montana.......	...	...	...	...	...	...	...	...	...	3	2	...	5
Nebraska.......	...	...	...	...	...	...	...	...	...	1	1	1	3
New Jersey.....	1	...	...	1	...	3	328	204	71	3	9	9	629
New York......	258	290	327	96	2	...	5	68	395	518	468	294	2,721
North Dakota...	...	...	...	...	...	...	...	...	...	2	...	...	2
Ohio...........	390	252	165	17	...	...	...	14	547	841	499	184	2,909
Oregon.........	32	12	25	4	...	...	...	1	1	2	5	3	85
Pennsylvania...	11	4	2	...	...	...	...	10	19	15	10	9	80
Texas..........	...	...	17	1667	3096	205	54	42	4	...	1	...	5,086
Utah...........	...	...	1	...	...	...	...	...	...	2	3	2	8
Vermont.......	...	...	...	...	...	...	...	...	...	2	...	1	3
Virginia........	...	...	...	...	...	...	32	106	42	1	...	...	181
Washington.....	2	2	2	...	...	...	149	478	95	21	14	3	766
Wisconsin......	11	11	15	...	...	...	...	...	45	127	41	7	257
Total........	1368	1159	999	1938	4242	607	1030	1918	3675	4910	2918	1186	25,950

TABLE 6

Carlot Shipments of Onions, Calendar Year 1921

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
Arkansas........	...	...	...	...	...	...	...	...	1	...	...	...	1
California, N. D.	258	96	42	33	11	90	151	324	680	464	349	113	2,611
California, S. D.	2	8	6	6	640	244	10	7	6	20	11	...	960
Colorado........	22	24	10	...	...	...	...	...	74	188	23	32	373
Georgia........	...	...	...	...	...	2	...	...	...	...	...	...	2
Idaho..........	...	1	2	...	...	...	...	...	20	16	4	...	43
Illinois..........	19	34	24	6	...	1	16	41	72	48	7	1	269
Indiana.........	380	379	277	18	...	...	9	255	520	169	136	180	2,323
Iowa...........	15	27	19	...	...	...	103	157	84	34	17	8	464
Kentucky.......	...	3	1	...	...	108	208	39	6	...	...	...	365
Louisiana.......	...	...	...	...	23	53	3	...	...	...	...	...	79
Maryland.......	...	...	...	...	...	82	58	3	...	...	...	...	143
Massachusetts...	288	350	382	141	8	...	112	209	606	316	185	212	2,809
Michigan........	72	89	88	21	8	...	...	7	104	114	20	12	535
Minnesota.......	29	30	9	2	...	...	...	1	55	62	22	11	221
Missouri........	...	...	...	...	...	...	10	3	1	...	...	...	14
Montana........	...	...	...	1	...	...	...	...	1	4	...	...	6
Nebraska.......	...	...	1	...	...	...	...	...	2	1	...	...	4
New Jersey.....	1	3	...	2	1	87	250	31	39	9	6	7	436
Nevada.........	...	...	...	...	...	...	...	...	1	...	...	...	1
New Hampshire.	...	...	...	...	...	...	...	...	...	1	...	...	1
New Mexico....	...	3	2	...	...	...	...	...	1	...	...	...	6
New York......	395	274	334	207	107	17	79	551	519	530	227	227	3,467
North Dakota...	...	...	...	...	...	...	...	...	...	1	...	...	1
Ohio...........	467	352	298	10	...	...	8	81	264	283	105	210	2,078
Oklahoma......	...	...	...	...	...	...	6	...	...	...	...	...	6
Oregon.........	1	2	3	1	...	...	...	1	65	132	35	18	258
Pennsylvania...	11	11	7	1	...	...	60	31	8	9	6	3	147
Texas..........	...	...	179	2042	1759	56	101	71	...	...	...	...	4,208
Utah...........	...	...	...	...	...	...	...	...	23	22	6	...	51
Vermont.......	...	...	...	...	...	...	...	1	4	...	...	...	5
Virginia........	...	...	...	...	...	84	64	...	...	...	...	...	148
Washington.....	2	12	9	6	1	...	233	229	34	19	15	14	574
Wisconsin......	76	71	31	7	1	...	...	...	29	24	8	6	253
Total........	2038	1769	1724	2504	2559	824	1481	2042	3219	2466	1182	1054	22,862

in the United States. The number of cars shipped during later years was variable: it was 22,027 in 1918; 20,874 in 1919; 25,950 in 1920; and 22,862 in 1921. It is thus seen that the markets in the United States have about reached the stage where they can consume so much and no more. This condition will probably last during the next twenty years, or until our population greatly increases. In that case, either the onion acreage will be extended, or more will have to be produced per acre.

In Texas, the Bermuda industry is now twenty-five years old, including the first two seasons at Cotulla. A few of those years have been disastrous on account of lack of transportation facilities, improper organization for marketing, or faulty distribution. There is no industry in the production and marketing of perishable crops but which has its bad years. The Bermuda onion growers have had their bad years; yet on the whole they have been favorable. The grower who tries to strike all the good years, and miss all the bad ones, usually demonstrates that either his judgment was in error, or the Weather Bureau let the season go wrong. In practice he usually catches the bad years and misses the good ones. After all, it is the old story over again: "He who keeps everlastingly at it" and never misses having only such acreage in onions as he can afford to carry without sacrifice, is the grower who wins ultimate prosperity.

CHAPTER II

VARIETIES

THE onion varieties differ as to color, size, form, season of maturity, productiveness, and storing quality. Of the varieties which are grown in the northern and western states may be mentioned the following: Those which belong to the Yellow Globe class are the Prize Taker, Yellow Danvers, Yellow Globe Danvers, Southport Yellow Globe, and Ohio Yellow Globe. Of the White varieties should be mentioned the Southport White Globe, New Queen, Italian Tripoli, Silverskin, and White Silverskin. Among the more important red kinds are the Red Globe, Red Wethersfield, and the Australian Brown.

In Texas there are three varieties of Bermuda onions grown. These are: Crystal White Wax, White Bermuda (also called Yellow Bermuda), and the Red Bermuda. Although the Red Bermuda is an early-maturing variety, it is not extensively grown, and, commercially speaking, is of little economic value. The Crystal Wax, usually spoken of as the "Wax" variety, thrives best in very rich fertile land. The White Bermuda is the variety which is most grown for commercial purposes. In Texas the experienced growers endeavor to grow about three-fourths of the main crop in White Bermudas and one-fourth in Crystal Wax. For heavy, sticky soils, the White Bermuda is well adapted. The Wax variety requires a somewhat longer period in which to mature. It also requires more care in havesting, ripening, and shipping.

With proper management there is not much difference as to yield, though, as regards shipping and carrying qualities, the Wax is more sensitive to unfavorable developments than is the White Bermuda. When the Wax reaches the market in perfect condition, it usually commands a premium, for a time at least, of 15 to 25 cents per crate (or bushel) over the White Bermuda. The premium is commanded by the pure clear waxen white color. If the onion becomes too much exposed to the direct sunlight after beginning to mature, a slight tinge of green develops, and in that condition they command no more, if indeed as much, as the White Bermuda. The overshadowing success and popularity of the Bermuda varieties keeps all other kinds far in the background in the irrigation districts of South Texas. In many districts of Louisiana Creole onions are grown extensively. The trucking districts about New Orleans and the Mississippi delta also grow great quantities of this variety. The Creole onion is better suited to the areas of greater rainfall in Louisiana and along the Texas coast, east of the Brazos River. The Creole is a strong, firm onion, of good keeping qualities, but is not grown extensively except in limited areas in Louisiana.

On the muck lands of Michigan, the Bermuda varieties are not grown. The best varieties for soil conditions there are the Yellow Globe and the Red Globe. As with every other commodity, certain markets prefer the yellow onion, and this is true of most of the Eastern markets; in the Middle West there seems to be a greater demand for the red sorts.

As already stated, besides the types of onions adapted for shipping, we should not omit those varieties which are grown as "top onions" and known as multipliers. These are sold as green onions in the early spring. In addition, garlic and leeks are frequently grown for market purposes, and there are similarly certain markets which consume considerable garlic as well as leeks. Both of these, however, are eaten mostly by the foreign element of the United States, especially those coming from Italy and some of the other Mediterranean countries.

The "top" or tree onion is grown extensively for spring or "bunching" onions. This variety is reproduced by means of small bulblets which are formed at the top of a seed stalk. The multipliers or "potato" onion, also known as spring bunching onion, reproduces by a division of the bulb. The large bulbs are planted to produce sets for the next year's planting. The small bulbs, or sets, are used to produce the crop of bunching onions for the market.

The leek belongs to the same class as the onion, but requires different treatment. The seed is sown in a trench and the plants thinned to about four inches in the row. After that, they receive the same cultivation as the onion. However, as soon as they have attained full size, the soil is thrown around the neck to a height of six or eight inches so as to blanch the fleshy stem, which is really the edible part. With the leek there is no true bulb formed, but the stem becomes uniformly thickened throughout. It is this part which is edible. Leeks are marketed in bunches like bunching onions. Garlic is planted either in autumn or early spring, by placing the subdivisions of the bulbs called "cloves," the same as onion sets. The culture requirements of the leek and garlic are but little different from those of the onion.

Soil Requirements

The best onions are produced in soils which have high fertility, good mechanical conditions, sufficient drainage, and which are free from weeds. Throughout the United States, there are at least three distinct types of soils in which onions are extensively grown: (1) clay loam, (2) alluvial loam, and (3) sandy loam. The first two types are usually found in the river valleys in the Delta regions near the coast. These are, as a rule, fertile soils, but need humus to lighten them. Otherwise, such soils will have a tendency to run together and bake after hard rains. This will be found to be a great disadvantage, especially after the seed has been sown and before the young plants have come up. Sandy loams with a well-drained clay subsoil underneath are well adapted to onions. Such soils require feeding with fertilizers before they can produce a paying crop. On the other hand, the quality of the product is unusually fine, because the mature bulbs are solid, heavy, and have good shipping and keeping qualities. Sandy soils may usually be supplied with humus through some leguminous cover crop which is plowed under, or through the application of stable manure.

Throughout the central and northern parts of the United States, onions are extensively grown in muck lands. Such soils usually contain large quantities of organic matter, making it loose and retentive of moisture. However, not all muck lands are adapted to onions. Spring muck lands or shallow muck lands underlaid with sand or gravel are satisfactory. Ordinarily, the quality of the muck may be judged by its vegetation. Black ash, maple, or elm indicates strong muck land. On the other hand, small brush is less desirable. The blacker and the finer of the muck lands are best suited for onions. In some of the onion districts of Michigan the muck is three to four feet deep and is underlaid with marl or a stiff, impervious, hard clay, which seems to maintain the water level at a uniform height, thus insuring a constant supply of moisture. In many parts of the United States, muck lands are not always adapted for onions until they are cleared, drained, and brought to a suitable state of cultivation. This would require two to three years' time.

In Texas, Bermuda onions are grown on a variety of soil types. Chief of these are the following: (1) Brennan fine sandy loam; (2) Duval fine sandy loam; (3) the Duval loam; (4) Duval fine sand; (5) Frio fine sandy loam; (6) Frio loam; (7) Frio silty clay loam; (8) Houston clay loam; (9) Houston loam; (10) Laredo clay; (11) Laredo silt loam; (12) Maverick loam; (13) Maverick clay loam; (14) Norfolk fine sand; (15) Nueces fine sand; (16) Rio Grande silty clay; (17) Uvalde silty loam; (18) Victoria clay; (19) Victoria loam; (20) Victoria fine sandy loam; (21) Webb fine sandy loam; and (22) Zapata fine sandy loam.

SELECTION OF LOCATION

Before one decides on the location of the main onion patch, the following factors are to be considered: (1) maximum yields; (2) nearness to water supply for irrigation and cost of delivery of same; (3) type of onion to be grown; (4) earliness of crop; (5)

nearness to a railroad switch; (6) nearness to the best paying markets; and (7) whether to be grown under irrigation or under dry farming. In addition to considering the location, we should remember that although the onion requires plenty of moisture during the growing season, the greatest trouble—and this is especially true of muck lands—is too much water due to poor drainage during the bulbing and harvest seasons. Under these conditions plants will die early in the summer, or the crop will be late in maturing and result in many "thick necks" or "scallions," that is, onions of poor quality, unsuited for storage or for shipment. In the poorly drained lands, open ditches are usually provided to drain the land. In some cases tile drains are required. Where surface drainage is poor, as it is on many of the muck lands, long narrow beds may be elevated by deep plowing, and drainage encouraged by leaving a double opened furrow between them.

In Texas the fertile sandy soils may be made to mature a crop earlier than the tight heavy black soils. A porous, friable black land which has a slight mixture of coarse gravel in the surface soil warms up quickly and produces a rapid growth and early maturity. This is also the case with the more porous red sandy or chocolate loam soils. An ideal soil selection would be to secure a tract of land which has both types of soil. The early maturing crop could then be produced on the quick-warming sandy soils, and a late crop on the heavier black loams. This would distribute the season for harvesting and marketing the crop to the best advantage.

The heavy black loams or dark chocolate soils, when planted reasonably early, will ordinarily produce the greatest average yields. If the crop is to be grown without irrigation, the location should be in an area where the rainfall during the growing period is ample. The soil should be of a type to receive and retain moisture well. For that reason it should have a good porous yet retentive clay subsoil.

The valleys of the Nueces and Rio Grande rivers of Texas contain great areas of deep silt loams which are well suited to onions. Such soils require frequent and liberal irrigation to retain sufficient moisture near the surface to make and mature a heavy crop.

The heavy tight black soils are very productive, have good clay subsoils from three to six feet deep, and require much less water at each irrigation than deep silt loam formations. The tight black soils have usually no gravel on the surface. The purely red sandy soils and the darker chocolate-reddish loams are quick to warm up, and readily respond to irrigation and cultivation.

CHAPTER III

SOIL PREPARATION

THE method of preparing the soil for onions does not depend on later cultural practices, such as irrigation or dry-farming. In either case the soil must be well prepared, because on this beginning depends a great deal the future of the crop. In well-drained lands plowing may be done in large blocks, whereas on poorly drained land the plowing is usually done in narrow beds. Finally, on very stiff clay soils it is desirable to plow in such a way as to leave a double furrow between each bed in order to carry off the drainage water. In this case the beds may be 75 to 150 feet in width.

In the reclamation of new muck lands, it is advisable not to grow onions the first year; the land should be devoted to corn, potatoes, or some other cultivated crop. In this case summer fallow and fall plowing are very desirable. This is followed by plowing in the spring and then by a thorough harrowing. In districts of heavy rainfall, the method of throwing up two-foot beds upon which two rows of sets are planted, will afford proper means of drainage.

In dealing with Bermuda onions, it is safe to say that there is no other crop which responds better to a proper and thorough preparation of the soil before the young plants are set out. If an onion crop has been grown upon the land the previous spring, it should be cleared of all small onions. These should be carefully gathered and destroyed, as they will harbor and carry over the onion thrips. If a crop of cowpea vines has been plowed under, the land should be harrowed and disced frequently with a tooth harrow until planting time. The borders and laterals should be made ahead of transplanting time, and the beds prepared and given time to settle somewhat ahead of irrigation.

It is not advisable to plow under heavy crops of green forage or rank foliage growth too recently before the transplanting period begins, unless accompanied by heavy applications of lime. Cover crops should be plowed under about two months ahead of transplanting season. They should be cut down or disced down and plowed under dry and left to decay normally, through the combined effects of frequent discing and harrowing and the moisture in the soil.

HARDPAN, PLOW SOLE, AND DEEP TILLAGE

The Bermuda onion is mostly grown under a system of frequent irrigations followed by shallow cultivations. Such a system necessarily packs the ground below the depth of cultivation. This compacted layer prevents either the normal distribution of soil moisture or a proper root development. Hence it is very important that a deep plowing should be given at least once during the year. This is best done soon after harvesting the onion crop. In this case the plowing should not be less than 12 to 14 inches deep and followed by the usual discing and cultivation. A shallow plowing should also be given sufficiently ahead of transplanting to allow the soil to become somewhat settled. This system applies especially to silt loams or alluvial soils. Should the soils have an inferior clay nearer the surface, then the plowing should be done with a subsoil plow, at least in the bottom of every other furrow. Any hardpan or plow sole will thus be broken.

Any soil with a thin layer of plow sole or hardpan cannot have a proper distribution of moisture through it. When plow sole and hardpan are broken up either with deep-tillage plows designed to plow and subsoil at the same time, or with ordinary plows followed by a subsoil plow in the bottom of the furrow, a normal distribution of moisture is assured. Hardpans or plow soles retard the growth of plants, and a full yield is never made on these spots, or acres, until this condition is remedied. Rapidity of growth and earliness of bulbing and maturing are always attained more rapidly and economically upon double-plowed lands, or those deeply plowed with deep tillage plows, provided such preparation is given early enough in the season to allow the soil time to settle.

Leveling the Land to a Uniform Grade

There is no factor of management which will contribute more to the success of the crop than that of having the land well leveled. Low or high places, in the beds or borders, not only necessitate greater expense in amount of water, but more time to apply it. The greatest disadvantage, however, is that the portions of the crop in the low places receive an excess of water, while in the high portions it receives an insufficient amount, both of which are injurious. Hence, no expense should be spared to test the surface of the land and eliminate any unevenness by whatever process may be required. After that, the crop may be managed according to any system of irrigation with the greatest facility, as well as the least cost of water and labor. This factor need not be urged upon those who have had experience with methods of irrigation. It is the factor, however, usually most neglected by beginners who have never raised crops under irrigation.

After the land has been plowed, and before being leveled, it should be thoroughly pulverized by the use of a disc harrow (Fig. 1, B). The type that is mostly used in Texas for onions grown on a large scale has a disc of four gangs in two sets. One combination is in front and the other is so arranged that the soil is first turned to the center and then turned outward again by means of a rear combination. This discs the soil twice and leaves it in a practically level condition. If one desires to smooth and level the soil behind the plow, an ordinary harrow is used, which levels, discs, and crushes the soil at the same time. Where the land has been plowed in the fall and needs replowing in the spring, a disc plow generally answers the purpose. For giving the land a final smoothing touch, one may use an implement which consists of a large number of small discs set in a wooden frame. It practically does the same work as a steel rake, but in a much more rapid manner (Fig. 1, C). Whatever tool is used for leveling, it should be able to fill and obliterate all sorts of depressions.

Determining the Grades; Making the Ditches and Borders

The grower should secure a qualified engineer to establish the grade lines for his main laterals and ditches. They should be run along the high grade lines

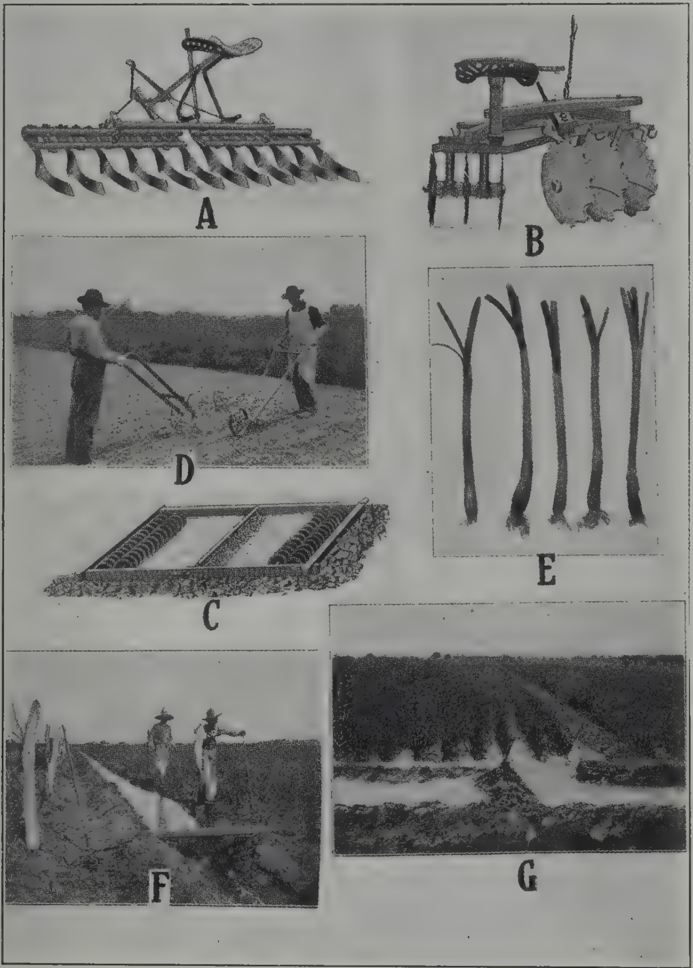

FIG. 1.

A. Acme harrow. *B*. Disc harrow used for refitting land. *C*. Meeker's pulverizing or smoothing harrow. *D*. Hand cultivation with wheel hoe. *E*. Green sets trimmed and ready for transplanting. *F*. Irrigation ditches in Bermuda-onion field in Texas. *G*. Irrigation of Bermuda onions in Texas. (*A* to *G*, after Farmers' Bul. 354.)

of the land, with sufficient fall to secure a good velocity to the flow of the water. When depressions of any extent must be crossed by these laterals or ditches, it is seldom advisable to do so by throwing up earthen embankments. Such dumps usually seep so much that they are not only a source of great loss in water, but are expensive to maintain. Besides, the adjoining soil becomes water-logged and unfit for use for crops. It is far better to install flumes or pipes, and the slightly greater cost is more than offset by its permanency as well as the saving in water.

The "head of water" and the type of land having been determined, the engineer will be able to locate the course of the several laterals and ditches, so that the series of beds from them will have the grade specifications best suited for the "head of water" available. Since the beds between borders must be level crosswise, it is important not to make them too wide on lands which have much slope. To avoid cutting too deeply at the high side in order to fill the low side, it is better to increase the number of beds by making them narrower. There is less soil to be shifted, where the drop is great, in making three ten-foot-wide beds level, than in the case of two 15-foot-wide beds. The engineer should bear in mind that during periods of excessive rainfall, the laterals, ditches, and borders should be so designed and built that they may be opened for drainage, and excess waters led off the land. During such periods it is as important to get the water off, especially if the onions are about fully matured, as it was originally to get it on to the crop (Fig. 2, C, D, E).

For making the borders between beds, no implement excels the Iron Age celery hiller (Fig. 2, A). It is two-wheeled, with seat for a driver, and is drawn by a team. Two large discs are used, one on each side, as in the case of a cultivator. With a lever, these discs can be set to run shallow or much deeper. The dirt is thus thrown to the center, and a small ridge or border is made to suit the needs of the particular land which is being prepared for irrigation. A leveling frame or Martin grader is used on the beds between borders, so as to fill in the narrow furrows alongside the borders with loose earth from the center of the beds. This leaves a perfectly smooth and level bed between the borders. The next process is to run crosswise of the beds and borders to establish the ditches and laterals. For this purpose no implement has proven more useful than the Martin ditcher and grader. A steady pulling team is hitched to either the No. 10 or No. 20 Model. Then the operator sets the blades of the ditcher so as to throw the depth and width of earth to one side along the grade lines already indicated. When the field has been crossed, a return trip is made along this furrow, but the earth is now thrown the opposite way, and a ditch, or lateral, is thus quickly established. For large laterals, the return drive only needs to be set as much wider as is wanted, leaving a tongue in the middle. This is thrown out by the next round. For heavy clay lands, or deep ditches, perhaps several round trips need to be made. If weeds or grass get started in the ditches, or laterals, the Martin Grader is used, care being taken to set and operate it so as to scrape off and throw out all rubbish and weed growth. Every irrigated farm should be equipped with one of these implements.

BORDER-ROWS, FURROWS, OR BEDS

The method to be practiced for successful onion culture under irrigation depends upon the topographical features and the character of the land. Lands which are practically level, or have only long gradual slopes, are best suited for the system of bordered beds and flooding. Lands which are too rolling, or which have too decided a slope, or are too flat and poorly drained, must be contoured, and the system of row or furrow irrigation used.

On lands which have sufficient clay in the surface soil to hold an abundance of moisture near the surface, and are porous enough to sub-irrigate well laterally, the narrow-bed system with two rows per bed may be used. Soils which are not sufficiently retentive of moisture at the surface, and in which waters of irrigation sink away to the lower levels too quickly, should be given the border "check" and flooding method. The row-border system usually designs to have the rows wide enough apart for horse cultivation. For the flood system, rows are planted twelve to fourteen inches apart, and hand or wheel-hoe cultivation has been found most satisfactory. The cost of horse cultivation by the border-row system is somewhat less than for hand cultivation, but the number of plants per acre will be less than by the border system. The system of narrow beds raised with two rows of onions is designed especially to afford quick drainage, when excessive rains occur during the period of crop maturity. Only those soils which sub-irrigate well may be operated successfully and profitably under this system. In case of excessive rains after the bulbs are about mature, the water may, under this system, be quickly drained off, so that the onions will be kept above the water line, and the danger of "water-logging" will be avoided.

BEDDED ROWS, FURROW IRRIGATION, AND HORSE CULTIVATION

By this method the rows are seldom less than sixteen inches apart. Narrow beds are thrown up and dragged down lightly so as to leave a smooth flat surface in which to plant the seedlings. These are placed three and a half to four inches apart in the rows. Horse cultivation is given, and usually two weedings are required. Three rows are cultivated at one time, the mule or horse walking down the middle row. Three straight shovels, or sweeps, usually four to six inches wide, are attached to Georgia stocks and then these are mounted strongly on a cross timber as a carriage. To this frame handles are attached so that the operator may guide the implement. A shaft and single-tree are attached ahead of it, to which the horse is hitched. Some growers mount five shovels, or sweeps, and cultivate five rows at a time. This is too wide for use on any but level lands. Where the slope is quite decided, not more than three rows should be taken at a time. The cost of transplanting is less, because fewer number of rows are required to be set per acre.

THE TWO-ROW-BED SYSTEM, WITH FURROW IRRIGATION, AND HORSE CULTIVATION

This system has been tested with two rows to a bed. The beds are prepared twenty-four inches from center

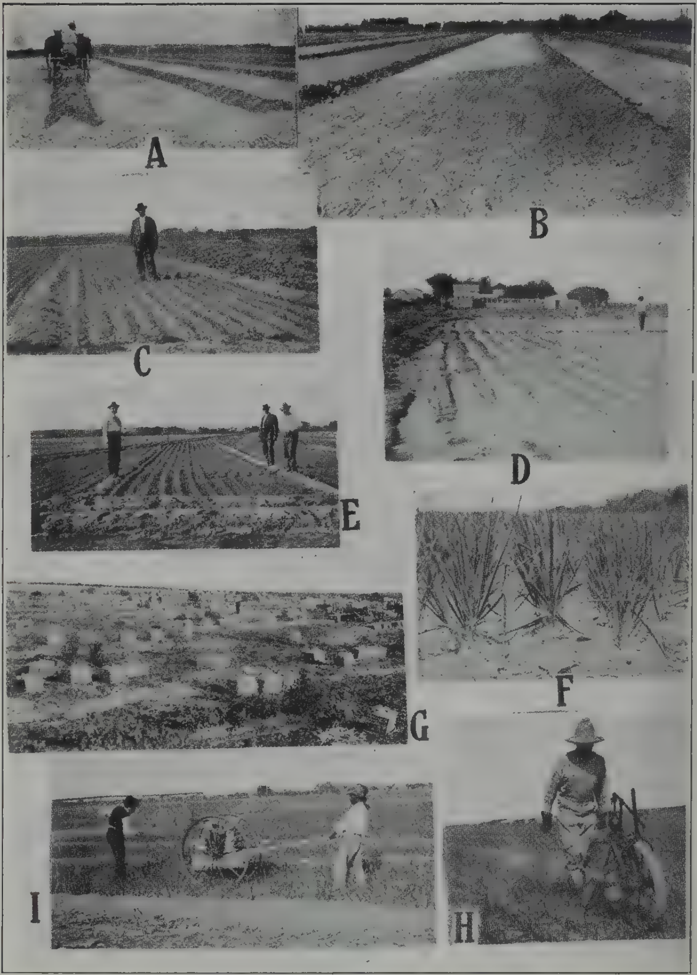

FIG. 2.

A. Making borders of beds with a "celery hiller." *B*. Check and border system, showing border of beds, seed drill rows, and first irrigation of seed-bed. *C*. Even stand in seed-bed because of proper leveling. *D*. Poor leveling resulting in water breaking loose and flooding other rows. *E*. After second irrigation from transplanting. *F*. Bulbing stage. *G*. Crating in field. *H*. Wheelbarrel tractor sprayer for young seedlings in seed-bed. *I*. Power sprayer pulled by hand.

to center so as to receive two rows of onions. These rows are placed eight inches apart on the beds, leaving sixteen-inch spaces between rows for irrigation and for horse cultivation. This system aims at placing eight-inch rows, and plants three and one-half to four inches in rows, to make the same number of rows and plants per acre as though the rows were twelve inches apart. It also aims to economize cost of cultivation. With very careful management, and with soil which sub-irrigates well laterally and holds moisture well, this two-row-bed system will usually give as great yields as the flat bed border and flood system, and will probably ripen the crop somewhat earlier.

THE FLATBED AND BORDER SYSTEM

This is the system most generally used by the great majority of the growers in Texas, especially of the Laredo district. It consists of throwing up narrow ridges or borders across the block of land to be planted (Fig. 2, B). The width of these borders varies with the grade or slope of the land. For level land it has been found that placing the borders twelve or fourteen feet from center to center is the most satisfactory distance. This enables the grower to secure eleven to twelve rows of onions, a foot apart, between the borders. If the surface has much fall, the borders should be made ten to twelve feet, center to center. Then an A-shaped leveling frame is pulled with the point and straight edge along the high side borders, so that the wing shoves the earth cut from the high side to the border on the low side. In this way the beds between borders are made to have a level surface.

It cannot be too strongly emphasized that where onions are grown without irrigation, it is just as important to prepare the land properly. Here, too, the surface must be made smooth and uniform. This will prevent low depressions from holding excess rain water. This is especially important in heavy soils.

CHAPTER IV

USE OF FERTILIZER

THE onion is one of the truck crops which responds liberally to the use of fertilizers. It is seldom that one can overdo in this matter, although this does not mean that it would be safe, for instance, to apply a heavy application of fresh manure before planting. Well-rotted manure uniformly applied will increase the yields. Bermuda onion growers in Texas and in the Southwest apply as much as twenty tons of barnyard or goat manure per acre. This is done in order to add the necessary humus to the soil.

Humus is the organic or combustible ingredient of the soil. In moist and more cool climates, the process of accumulation is gradual. The direct rays of the hot sun, under the condition of a very dry air, frequently oxidizes some of the organic matter, and this means a dissipation of the humus.

Humus is the substance in the soil capable of retaining the free nitrogen and saving it from washing out. It also is the ingredient which retains the moisture of the soil for use of plants. It is the substance which so largely gives proper texture to the land. A soil without humus is usually spoken of as "dead." Hence the first step is to increase the supply of humus in all onion lands, if they are to yield maximum profitable returns.

Loss of humus may have three causes. It may be due to: (1) Fermenting bacterial organisms which are present and constantly at work in all soils rich in organic matter. They maintain a constant decomposition for all growing crops, which will gradually reduce the humus contents, should there not be a proper proportion returned to the soil each year. (2) In the hot dry climates best suited for Bermuda onion culture, exposure of the soil to the direct rays of the hot sun by frequent clean cultivations results in a gradual combustion of the humus. (3) Being lighter than the mineral particles of the soil, rains may wash and leach it out. The loss from leaching or washing may be largely overcome by good methods of cultivation. Gradual changes in humus through soil bacteria is a necessary process to develop soil fertility. Hence, proper management should provide either that growing crops may take up the plant food as it becomes available, or that the new supply of humus be sufficient to retain it. Cover crops are the greatest allies in such a plan of both developing and retaining available plant foods in the soil.

The soils of temperate climates with plenty of moisture accumulate humus, but the proportion of nitrogen is small, often amounting to only a fraction of one per cent. In the more arid and warmer climates humus accumulates more slowly, but contains relatively more of nitrogen, as well as of other available plant foods. For this reason the first yields on such lands are heavy, but at the same time the consumption of humus and other available plant foods takes place in the same ratio.

Whenever there is not sufficient humus in the soil to hold in combination the much desired nitrogen and other quickly available plant foods, there is a rapid depletion of all soil elements. Onion lands are planted so closely and cultivation is so intensive that maximum yields are sought, regardless of any other consequence. Hence, to avoid disappointing results in succeeding crops of onions, the greatest amount of organic matter possible should be returned to the soil each year. Onion soils should always be kept well supplied with organic matter. The use and value of commercial fertilizers should not be underestimated, but for an onion crop humus, and the consequent more friable soil, is of primary importance. Quickly available fertilizers should be used only on land containing plenty of humus and growing crops. Otherwise much of the nitrogen is lost.

Application of Farm Manures

In the use and application of farm manures the grower should consider the type of soil most in need of them, the kind of rotation practiced, the time and rate of application suited for these crops, and, above all, he should see to it that a sufficient amount is applied to any given area, rather than scattered thinly over too great an area. It is more desirable to manure a small area sufficiently each year than to apply a little of it to large fields. Well-rotted farm manures should be properly scattered over the surface of plowed land, and well disced in. It should never be plowed under very deeply if it is to give up much of its plant food quickly to the crop which is to be planted soon after.

The best results from barnyard manures are often not secured until the second, or even the third year of their application. Composted manures should be applied and plowed under a couple of months ahead of seeding, or transplanting. In the irrigation districts, the land should be furrowed and irrigated after manure has been plowed under and then well disced and cultivated, so as to destroy the weeds which will germinate and grow rapidly after the irrigation. Large quantities of fresh manure applied and worked in just ahead of seeding or transplanting is likely to develop an excessive growth of top with no proportionate bulb development.

USE OF COVER CROPS

The Beeville (Texas) Substation has clearly demonstrated the value of growing a crop of cowpeas each year after onions have been harvested, and of plowing under a good crop of vines and leaves. This assists in building up the fertility of the soil so rapidly as to justify the gradual decrease in amount of commercial fertilizer. If, in addition, a fair amount of barnyard manures can be applied, the yields will be increased proportionately, even though no commercial fertilizers are used.

The results of experience do not argue against the profitableness of commercial fertilizers for use in the growing of an onion crop, but rather that the rate of profit per dollar invested in cover crops and manures is greater than for the investment in commercial fertilizers, unless they be used upon soils developed into proper texture through a previous supply of manures and cover crops. On soils built up in that way a fair amount of quickly available fertilizers will show proportionately more profitable results than when the same amount is applied upon soils lacking in organic matter.

The following legumes have proved valuable in the Bermuda onion district of Texas. The whippoorwill pea makes a more rank growth than the black-eyed pea, though the latter succeeds well and yields more peas. If an onion crop is harvested early, either of these two legumes will prove valuable. For later planting during the heated summer periods, the velvet bean, and especially the tepary bean, will be more satisfactory. For eelworm-infected soils the Florida beggar weed, the peanut, the Laredo Soy bean, or the velvet bean should be used exclusively. They are resistant to the attacks of this soil parasite.

When great quantities of green manure are plowed under, it is important to add broadcast a thousand pounds of lime per acre in order to neutralize all acids formed. If the land is naturally well supplied with lime, no further application may be necessary. In no case should seed be sown or sets transplanted in a field where a cover crop has been worked under until the fermentation period is over. If crops are plowed under a month ahead of seeding or transplanting time, and irrigated if necessary, the decomposition in the presence of enough lime and moisture will have passed the danger period.

Commercial Fertilizers

The productiveness of any given soil is controlled largely by the element of plant food in which it is most deficient. A soil is productive of any given crop relatively only to the extent that the most deficient element permits it to be. Hence, if there were phosphates and potash in a soil sufficient to produce 500 bushels of onions per acre, and the nitrogen element sufficient to produce but 300 bushels, the tendency is for the yield to gravitate to the limitations of the nitrogen elements. It is not profitable under such conditions to supply any food element other than nitrogen to that soil. It is not wise to apply fertilizers without first determining which is the deficient element in that soil. In no other way can commercial fertilizers be used on soils with the greatest profit and without waste.

To obtain the highest results from the use of commercial fertilizers, the organic matter in the soil should be maintained so as to provide conditions of texture and porosity which will sustain the proper relations between solubility of plant foods, as well as their activity or availability for assimilation through plant growth. With the mild climate and a continuous growing season for the region of southern Texas, it should not be necessary to buy nitrogen fertilizers, except as top dressing for a quick finish. They are the most expensive to buy and at the same time the most easily accumulated through proper soil management.

Commercial fertilizers stimulate vigorous plant growth, not because the fertilizer has fed the crop, but rather because it has enabled the plants to draw more heavily upon the fertility of the soil. This process gradually exhausts fertility by decomposing the humus and liberating plant food. If the liberated food is not taken up by the growing crop, it will be lost through leaching. This explains why reasonable amounts of commercial fertilizer on rich soils will usually show more profitable results than the same quantity applied to poorer soils.

The practice of using at the first application only a portion of the total amount of fertilizer to be used ultimately is to be commended. If all is applied at one time, a vigorous plant growth may be encouraged at the start at a rate which the plants often are not able to maintain until the time of maturity. This is especially true because of drawbacks to growth from freezes or other unfavorable weather conditions. After such a "check," recovery will be more rapid where the fertilizers are applied in small amounts at intervals during the growing season.

USE OF LIME

Lime is not directly a plant food, but it is used primarily to correct soil acidity. If the soil is rich in lime, and is alkaline instead of acid, no lime is required. Whenever needed, lime should be applied broadcast at the rate of not less than 1000 pounds per acre on all soils showing traces of acidity. Its use on stiff clay lands will assist in correcting the texture and develop a more satisfactory friable condition.

Besides neutralizing soil acidity, lime acts directly on the humus and organic matter and promotes decomposition and a more rapid liberation of plant food.

USE OF PHOSPHATE (14 to 16 per cent available)

If the grower desires to secure earliness in maturity, a liberal application of this element spread broadcast and disced in, or drilled into the soil and harrowed, will answer the purpose. Usually not less than 300 pounds per acre should be applied ahead of seeding or transplanting.

USE OF POTASH (MURIATE)

For the Bermuda onion crops grown under irrigation, and especially if the soil is fairly well supplied with lime and organic matter, muriate is used, rather than the sulphate of potash. Potash contributes to the flavor and keeping quality of the crop. To promote further earliness in maturity it is well to use 100 pounds muriate of potash in combination with a like amount of nitrate of soda per acre. This mixture should be applied, in two equal portions with fifteen-day intervals, as a top dressing, just ahead of the period when the swelling and formation of bulbs is about to begin. If the season has been favorable, a second application of potash is not likely to be required. Should the crop have been transplanted late, then a top dressing in combination, as suggested, becomes advisable. In either case it is assumed that proper amounts of acid phosphate have been supplied early in the growth of the crop, and that the soil has been well prepared. Each application should be followed quickly by an irrigation. For other varieties of onions in northern districts, especially those without irrigation, the potash should be applied along with the phosphate.

USE OF NITRATE OF SODA

This is often applied as a top dressing to hasten the completion of the bulbing process. Not less than 70 pounds, nor more than 150 pounds, nitrate of soda per acre should be used in one application, and this should be followed promptly by an irrigation. Should climatic or other conditions prove unfavorable after the first application, another 100 pounds per acre will often prove profitable. It requires experience to judge the condition, growth, and progress of the crop, so as to determine when the two applications of nitrate of soda are to be given. For non-irrigated districts the applications should be given quite early in the growth of the crop.

USE OF SULPHATE OF AMMONIA

The use of sulphate of ammonia becomes advisable when the soil is known to be well supplied with lime. For Bermuda onions recent tests by the authors have shown favorable results in comparison with nitrate of soda. Sulphate of ammonia usually contains 24 to 25 per cent available nitrogen. It seems also to act more slowly and continuously for a longer period of time. When maximum results are to be secured through a vigorous, steady growth, it will be well to consider carefully the use of this fertilizer. It is higher priced per ton than nitrate of soda, but it also has a greater per cent of available nitrogen covering a longer period of assimilation. Fewer tons will need to be handled for any given acreage, because 70 pounds per acre will supply an amount of nitrogen equal to that contained in 100 pounds of nitrate of soda. Northern growers, especially in the non-irrigated districts, will do well to use this fertilizer more generally.

BAT GUANO

This is a valuable fertilizer for onions. Whenever it is possible to secure liberal shipments, it should be used freely. It is a good source of nitrogen, well balanced with phosphates and a trace of potash.

USE OF COTTON-SEED MEAL

This is the most valuable single fertilizer to drill or disc into the soil ahead of seeding or transplanting. It decomposes gradually, and will tend to maintain a more uniform growth. About 800 pounds per acre should be applied and disced in about thirty days ahead of transplanting. When the crops are well rooted and growing, another 800 pounds should be applied.

A top dressing of nitrate of soda and muriate of potash, equal parts, applied ahead of bulbing time, at the rate of 100 pounds per acre, is advisable, if it is desired to rush the maturity of the crop. If applied too late, nitrate of soda will promote vigor of growth, for a time, at the expense of early maturity.

TANKAGE

Tankage ranks as one of the best mixed fertilizers for onions. It should contain 4.5 to 5 per cent of nitrogen, and not less than 8 per cent of available phosphoric acid. Eight hundred pounds per acre should be worked into the soil just ahead of seeding or transplanting. A second application of 800 pounds should be given about six weeks after the crops are well rooted. When bulbing is about to begin, apply a top dressing of nitrate of soda and muriate of potash, as indicated above when cotton-seed meal has been used.

FERTILIZING VIRGIN SOILS

Throughout the southern states there are great numbers of truck growers settling upon unimproved lands. Soils fresh from the grubbing and plowing can be aided profitably by the application of a mixture of 1000 pounds of cotton-seed meal and 300 pounds of potash in the form of kainit, applied in two equal portions as advised for cotton-seed meal. This should be drilled in shallow or broadcast, and disced in. The first year's experience is likely to show which element is most deficient, and succeeding crops may be fertilized more intelligently.

FERTILIZING OLD LANDS

It is intended to include all soils in this group not virgin or first-crop lands. If, for any reason, it has not been possible for the grower to build up the proper fertility for an onion crop, and the prevailing conditions seem to warrant urging the crop along with its growth and maturity, it will pay to give a reasonable application of a complete fertilizer. This should be proportioned about eight to ten per cent of acid phosphate; four to five per cent of nitrogen; and two to three per cent of potash. This mixture, if applied at the rate of 800 pounds per acre, and well worked into the surface of the soil before seeding or transplanting, will give the crop a good start and help to push it through delays or unfavorable conditions. A second application of the same amount is to follow thirty or forty days after the crop is growing.

Generally speaking, a fertilizer that is adapted for Irish potatoes is also suitable for onions. Such a fertilizer is to contain four to five per cent of nitrogen, eight to seven per cent of acid phosphate, and two to four per cent of potash. It is applied at the rate of 1000 pounds per acre.

The following all-around fertilizer formulæ are recommended by W. R. Beattie:

(1) For use in the southern states:

Nitrate of soda	200 lbs.
Cotton-seed meal	750 "
Acid phosphate (16%)	750 "
Muriate of potash (50%)	300 "

(2) For use in sections where cotton-seed meal cannot be obtained:

Nitrate of soda	300 lbs.
Dried blood	500 "
Acid phosphate	800 "
Muriate of potash	400 "

(3) For general use:

Sulphate of ammonia	200 lbs.
Dried blood	300 "
Cotton-seed meal	300 "
Acid phosphate	800 "
Muriate of potash	400 "

Commercial fertilizer, when used, should be applied only a short time before sowing the seed and should be well distributed and thoroughly worked into the soil. In this connection, a one-horse fertilizer distributor will answer the purpose well. On a small scale the fertilizer is, of course, applied broadcast by hand.

On muck lands only well-rotted manure should be used and it should be applied during the fall. Such lands also respond favorably to the use of commercial fertilizers. The use of lime on muck soils will depend on the acidity of that soil. Unless the soil is distinctly acid, lime will have a tendency to decrease production. The amount of lime to use will depend on the acidity, but it should not be higher than 1000 pounds per acre. Usually, muck lands underlaid with sand or gravel have a tendency to be acid, and they are generally benefited by an application of lime.

CROP ROTATION

The school of experience has taught those who are teachable that crops maintain higher yields if alternated properly. Some crops fail in their yields less rapidly than others. The onion is one of these; in fact, it is almost an exception, if only the proper texture and mechanical conditions of the soil are maintained, as explained under soil management.

Most cultivated crops use about the same ingredients from the soil, the difference being largely in the relative proportions of each element. Should it work a disproportionate hardship to rotate for an entire year, as would be the case with Bermuda onions, the difficulty may be overcome by using well-rotted manure. If this is not available, organic fertilizers, such as cotton-seed meal, will aid greatly. If not exposed to leaching rains, cowpen manure where cattle have been fattened upon cotton-seed meal, is most excellent. In the South the inoculated leguminous crops which grow and mature quickly between the seasons for onion crops are most valuable for cover crops to plow under. If crop rotation should be practiced with the onion crop, an intelligent system is to be adopted. This is illustrated in Table 7 from Texas Experiment Station Bulletin No. 161.

TABLE 7

Plant Food Removed by Crops in Pounds per Acre

	Phosphoric Acid	*Nitrogen*	*Potash*	*Valuation per Acre*
Corn, 40 bu. corn and cob	19	38	13	$ 9.52[2]
Wheat, 25 bu	13	29	8	7.06
Oats, 40 bu	10	25	7	6.02
Cotton, 250 lbs. lint	0.1	0.8	0.7	0.21
Potatoes, Irish, 100 bu	10	20	36	6.76
Potatoes, sweet, 200 bu	20	28	72	11.12
Alfalfa, 4 tons	50	183[1]	143	48.18
Sorghum, 3 tons	29	84	134	26.58
Sugar Cane, 20 tons	15	153	44	34.14
Onions, 30,000 lbs	37	72	72	20.93
Rice, 1,900 lbs	12	23	5	5.62

[1] A part of this nitrogen comes from the air.

[2] Phosphoric acid is rated at 6 cents per pound. Potash the same, and nitrogen 20 cents per pound. Estimate is based upon unmixed fertilizers. Mixed, or so-called complete fertilizers, would really show greater cost items than shown above.

From an inspection of Table 7, it is evident that, to maintain a high fertility in soils to be devoted to onions, it would not be wise to precede it with a crop such as sorghum. As compared to onions, sorghum taxes the phosphate contents of the soil slightly less, but it draws much more heavily on the nitrogen and virtually requires double the amount of potash. The total value of soil ingredients taken out by a 30,000-pound onion crop is about $20.93 per acre, as compared to a three-ton sorghum crop, which is $26.58.

CHAPTER V

SEED-TESTING

ONION seed are frequently of low vitality. This may be due to the use of old seed or to the fact that the seed are frequently harvested during wet weather and stored in a damp place. This causes them to go through a heat and destroys the viability. Before planting the seed should be tested for germination, because a poor germination means not only loss in the seed, but a loss in the expense of preparing the soil for replanting and the prospects of a late crop. The quickest method perhaps in testing the seed for germination would consist in picking out at random a sample of about 300 seed. These are placed between two sheets of moist blotting paper or moist cloth on a plate and put in a warm room. If the seed are viable, they should give about 90 per cent germination. Old seeds are always inferior on account of low germination. They usually lack in vitality and seldom produce entirely strong vigorous plants. Good fresh seed is always cheaper at almost any reasonable price.

Another method of testing the viability of onion seed should be to float them before planting. This is done by pouring the seed into a tub or bucket of water and stirring them vigorously. All the light and defective seeds will float and should be skimmed off and thrown away. This is especially important when the seed is to be drilled in rows to a stand. The good heavy seed should be allowed to soak several hours; then they should be spread out on a burlap sack in the open air to dry enough so that they will work through the usual seed drills freely. As a result of the soaking, the seed will germinate more quickly and one irrigation of the seed-bed will thus be saved to secure a good full stand. This is especially true if the seed-bed has been irrigated and worked over just ahead of the drilling in of the seed. Owing to the fact that the seeds have been swollen somewhat by the soaking, the seed drills must be set with somewhat larger openings to allow an equal number of seeds to pass. With good seed not more than three pounds dry weight should be required to produce an abundance of plants for one acre of onions in the field.

Bermuda Onion Seed

Until recently all seed of Bermuda varieties used in Texas were grown on the Canary Islands and imported from Teneriffe. Seed of the White Bermuda was imported at a cost of $1.00 to $1.50 per pound to the Texas grower; Crystal Wax was seldom less than $1.50 to $2.00 per pound. During the first fifteen years the Bermuda onion industry of Texas depended wholly on seed from the Canary Islands. During recent years, however, there occurred three great crop failures in the onion-seed production of those islands. In addition, the uncertainty of the time of reaching the growers, the import duty, and many other items have helped to place the Texas onion growers in a receptive mood to buy seed from other sources. In the meantime, California seed growers were experimenting with methods of producing Bermuda onion seed successfully and profitably. In the fall of 1914 the first considerable quantity of California-grown seed was tested by one of the authors in coöperation with the most extensive onion growers in the Laredo district. The tests were satisfactory in every way, as the California seed were found to possess high germinating qualities. The plants grew off vigorously and produced a heavy yield of uniform onions of good shipping qualities. As a result, thousands of pounds of California-grown Bermuda onion seed are now used in Texas and other States.

Methods of Laying off Seed-beds

The seed-beds are laid off in borders about twelve to fourteen feet from center to center. This enables the grower to drill in an average of about eleven to twelve rows to the bed. The rows should be twelve inches apart, and not usually more than 100 feet long. On some soils on which the water spreads quickly the rows or beds may be made 150 feet long. That means that the cross laterals should be established every 100 to 150 feet, depending upon the nature of the soil and the slope or fall which it may have. Very nearly level beds should be made shorter than those having liberal fall or grade. If the ground has barely fall enough for the flow of the water, the beds should not be made much in excess of 100 feet in length. It will be found more satisfactory in this case to irrigate more frequently than to give the young seedlings an excess of water during their early and tender stages of growth.

It is exceedingly important that the beds be carefully leveled both laterally as well as lengthwise. A seed-bed with either high or low places is very objectionable. In the low spots the seeds will rot, and in the high places the plants will die or linger for want of moisture.

For types of soil which bake or run together from irrigation, the seed-bed acres may be laid off into slightly raised rows fourteen to fifteen inches apart. The soil should have ample time to settle ahead of seed-planting or irrigation. If the soil is inclined to crust, irrigation is given between the rows, in order to moisten the beds ahead of planting. Then the seed are drilled in as soon as dry enough to work well. The narrow raised rows should never be flooded, that is, completely covered, as that would develop a crusting over the seed, or about the young seedlings just emerging.

Preparation of the Seed-bed. In order to get the most vigorous and uniform plants, the seed-bed should be given a thorough plowing, discing, and frequent harrowing for a period of at least three months previous to the planting of the seed. In the beginning of this preparation the land may be irrigated to put a good season into it. This is to be followed again by repeated discing, harrowing, dragging, and leveling. The seed-bed soil must be well aired and thoroughly worked. It should be kept perfectly free from all weeds by frequent clean cultivations. It is a bad policy to permit lands that are to become the seed-beds to become overgrown with weeds.

Time of Sowing. There is practically no uniformity as to the time of planting the seed. This varies with the locality and the aims and purposes of the individual grower. In the Laredo districts of Texas there are many growers who strive for earliness at almost any cost. These often plant their seed as early as the fifteenth of August. From that time on, there are scattered plantings through the month of September. The bulk of the seed at Laredo is planted from September tenth to the twenty-fifth. Some of the most experienced Laredo growers prefer to plant as near to September fifteenth to twenty-fifth as is possible. Throughout the Bermuda onion district there are those in each locality who plant early, but for the counties of Maverick, Dimmit, Zavalla, and La Salle, Texas, the best average date for the planting period varies from September fifteenth to as late as October fifth.

Amount of Seed for Sowing. The amount of seed to be planted per acre of seed-beds varies. Those who plant during August, or early in September, will do well to drill in not less than twenty-five pounds per acre. If the weather at that time is very dry and hot, it may be well to plant thirty pounds per acre. The value of this heavy seeding is that the great number of small plants shade and protect each other from the heat of the sun. For the period of planting from September twenty-fifth to October fifth, it is neither necessary nor advisable to use more than twenty-five pounds of seed per acre. Experience has demonstrated that for no seed-planting period should less than twenty pounds be used per acre. The disadvantage in planting such heavy quantities of seeds in drills is to pile them up thickly in the narrow furrow opened by the shoe of the average seed drill. This objection, however, has been practically overcome by the use of a new shoe design attached to the lower end of the drill, which spreads and distributes seeds over a wider area. This makes a strip of plants about two inches wide, instead of half that width, and results in greater numbers of uniformly vigorous plants.

Depth of Sowing Seed. The depth at which the seed should be planted in seed-beds which are to be irrigated depends somewhat on the nature of the soil. It should never be planted deeper than one inch in the lighter sandy types of soil and the silt loam formations. For the heavier, more sticky soils, the seed should not be planted more than one-half inch deep. Some growers irrigate the seed-bed thoroughly before seed-planting, while others claim that best results are obtained by putting in the seed dry and irrigating afterwards. The factor which really counts is the type and nature of the soil, and its ability to hold moisture well near the surface. The heavy soils which are very retentive of moisture may be irrigated previously to planting; however, they should be allowed to become dry enough for thorough working and pulverization ahead of planting. Under proper management of these soils, enough moisture is retained to encourage good germination before an irrigation is required.

For soils of the sticky types it is important not to irrigate too heavily at any one time, especially before the seed is up, in order to prevent the soil from packing and crusting at the surface. This will necessitate a second irrigation a few days after the first. If irrigation precedes seed-planting, the seed should not be sown until the soil is dry enough for the seed drill to work well and cover the seed without caking the soil. Should the seed be planted while the soil is yet too wet, a poor germination and poor plants are likely to result.

Whatever the type of the soil, the critical stage in the life of the young seedlings is just as they come through. The grower must watch the moisture conditions vigilantly. The soil above the seed row should never be allowed to become crusted. The young plants are not able to come through a crust; hence, at this stage they should be given a light irrigation, just enough water being used to moisten the surface and keep it from crusting until the plants come through. Frequently, beginners will attend carefully to every detail up to this point and then get only half the number of plants they should because of a day's delay in getting a light irrigation on the seed-beds just as the young plants are trying to break through the crust.

Cultivation of the Seed-Bed. Once the plants are up, careful and frequent shallow cultivations should be given to develop a deep and profuse root system. There should be several cultivations between each irrigation, on most soils. In fact, the seed-bed should be irrigated often enough only to keep the plants growing evenly, vigorously, and uninterruptedly. There is nothing that means more for the ultimate success than to prevent the young plants from becoming stunted or seriously checked in their growth. A steady even growth is very essential for a uniform crop of good marketable onions. Three irrigations, in addition to the two to bring the plants up properly, usually suffice to make the plants reach transplanting size. This usually requires from sixty to seventy days from the time of sowing the seed. Under favorable conditions sets reach the quill size in fifty-five days. Transplanting may begin at that time, and when this operation is well in progress, the sets will be sixty to seventy days old, and many of them will have attained the size of a lead pencil. Plants of that age when transplanted form a new set of roots more quickly than those which are a hundred days old or older.

Advantages of Transplanting. These may be briefly enumerated as follows: A uniform and nearly perfect stand, greater uniformity as to size and maturity, larger yields, economy in cost of weeding, economy in irrigation, and higher prices for grade and quality.

The principal disadvantages are that the advantages named above do not always materialize to the degree expected. The character of the season during the period of growth as shown by the rainfall, sunshine, cold weather, or even freezes, may all contribute to minimize the advantages. Should the crop be retarded too much by unfavorable climatic conditions, then the greater cost of production may not secure a proportionate increase in the yield or profits. The cheaper methods with a lesser yield occasionally show a greater net profit, or rather a lesser net loss. In the last analysis it is the cost of production which controls the measure of profit. Each grower should consider carefully all factors and then adopt that system which seems the most free from risk in production, at a cost which will insure a profit when average price levels prevail during the marketing of the crop.

Unless the best seed has been purchased, and the plants are properly grown, vigorous, and well-rooted, the transplanting method may fail, at least partly, in so far as concerns the yield and the uniformity of maturing.

Transplanting. When onion seedlings are pulled out for transplanting, both roots and tops are trimmed off (Fig. 1, E). The roots are cut to one-half inch in length to facilitate transplanting and to secure more uniform setting by the laborers. Trimming the tops to at least one-half checks the rate of transpiration and thereby encourages quicker formation of new roots.

When the seedlings are somewhat less than lead-pencil size, they should be pulled and carefully culled. All small plants among a lot of seedlings should be thrown out. Only those which have made vigorous growth and attained the larger size for the time they have been growing should be used. It is more profitable in the long run to cull out a fourth or a fifth of the plants at the time of transplanting, than to cull out the undersized and poorly-shaped onions at the grading table after they have received the expense of a season's culture to produce them. If plants are scarce, the culls may be saved for transplanting in separate fields. Experienced growers agree that a small plant, from whatever cause, set among large vigorous ones, will not be able to maintain itself, often dies, and but few ever make commercial-sized onions. The seed-beds should be given their last irrigations sufficiently ahead of pulling the sets, so that the ground will be dry enough to operate on, and moist enough so that the plants pull easily. The plants having been carefully culled are distributed along the rows for transplanting.

If the maturity of the crop is going to be thrown far into the dry hot season during May and June, then the plants should be set more deeply than for crops maturing during March and April. This is done to avoid injury to the bulb from the direct heat of the sun. The bulbs should be deep enough to have a thin dust mulch to protect them from sun scald. With a backward, cold season, the deep-planted onions will mature more slowly than those planted more shallow.

The white varieties of onions, such as the Crystal Wax, should always be devoted to the more sandy soils where they may be planted slightly deeper and be better protected from "greening," which occurs if the bulb is too much exposed to the direct rays of the sun. The White Bermuda may be planted more shallow, as it is better suited to the heavy black soils than the Wax. It is, therefore, evident that an onion grower must be careful of soils and seasons, and quick to judge of conditions as they develop.

The depth for transplanting is controlled largely by the nature of the soil and the season of transplanting, and hence the probable time of harvest. If the soil is a heavy clay loam, and the sets are transplanted early, they should not be set less than an inch nor over one and one-half inches deep. In the case of this type of soil the onion bulb is almost on top of the ground, and for this reason it is advisable to transplant as early as is consistent for the locality in which the crop is being produced. The sandy soils should be held in reserve for the last or latest transplantings.

Considerable space was given above to a discussion of seed-bed operations where the seedlings are raised for transplanting purposes. In many states, however, the main crop is produced from seed drilled in directly to a stand.

In the northern onion-growing districts the seed is sown as early in the spring as the soil can be brought to the proper condition. When the soil has been brought to a smooth, even surface and is fine and mellow, the seed is sown by means of one of the common seed drills. The hand drills which sow one row at a time are extensively employed, but many of the larger growers employ a gang of drills hitched together and plant from five to seven rows at once. A more even distribution of the seed will be secured by the use of the single-row hand drill owing to the closer attention that can be given the one machine. The first row may be planted with a line, and after this the marker on the drill indicates the next row. The drills are so arranged that the shoe and covering blades can be regulated to cover the seed at the proper depth, which will vary with different soils.

ROOT SYSTEM OF THE BERMUDA ONION

Digging tests made by the authors demonstrated the fact that plants forty days old in seed-beds have developed roots to a depth of fifteen to eighteen inches. At the end of sixty days, many of the roots have penetrated to a depth of two feet. Plants not permitted to remain in seed-beds longer than seventy to eighty days usually develop but few shallow spreading roots.

During November transplanting season, if the soil is moist and warm and irrigated promptly after transplanting, with warm weather conditions prevailing, digging tests have shown that within two and a half to three days two to six new roots have started. Within four or five days later, plants were dug showing six to twelve new roots, from half an inch to two inches long. A few days later, or within ten days from transplanting, the roots may develop ten to fifteen in number, and from two and one-fourth inches to five inches in depth. Hence it is evident that vigorous plants transferred to new and well-prepared soil should be followed promptly with irrigation. Delays in developing new roots may not kill the plants, but will probably delay their growth, with possibly a lesser yield at maturity.

During the greater period of growth, or what may be called the vegetative growth, the roots of the transplanted onions go deeply into the soil. Many plants have been found, which were sixty to seventy days old in the field, with roots down between three and four feet into the soil, except in the case of tight clay soils, which are not penetrated more than two to three feet. At about the age when the onion prepares to swell above the crown, the plant begins to throw out roots which grow laterally. There soon develops a mass of lateral roots near the surface of the ground. When the spaces between rows begin to be filled with numerous surface-spreading roots, the grower should take warning that the crop is preparing to bulb. During this period, cultivation should always be very shallow, or cease entirely.

CHAPTER VI

IRRIGATION

IN the Bermuda onion districts of Texas installation of irrigation equipment, as well as the selection of the system for the distribution of the water over the land, is estimated in terms of the "second foot" of water as a unit. In practice this means a flow or discharge of 450 gallons of water per minute. If the water is delivered to the land through flumes, then the only consideration is the loss through evaporation. If it must flow through long stretches of earthen laterals or ditches, there is an additional loss of water through seepage. Therefore, if it is desired to maintain a constant delivery of 450 to 500 gallons of water at the discharge of the laterals into the ditches and beds, a much higher capacity must be provided for at the pump. With fields properly leveled to a grade and with correct distribution of the laterals and ditches, one trained workman should be able to direct the distribution of water from a discharge at the beds of 450 gallons per minute. A lesser discharge will force a proportionately slower distribution over the land, which increases the cost of irrigation.

The width and length of beds for flood irrigation, or of single rows, or row borders, should all be determined on the basis of the "head of water" which the grower is able to secure and maintain constantly and economically. Hence, it is of primary importance to determine accurately the volume of water which the grower may depend upon.

For the Laredo district in Texas the acre length (208 feet) is the one in most common use. For the level black clay soils which take water slowly, a fall not to exceed two to three inches is allowed. The gray river-silt loam soils are given a drop of about four inches and the sandy loam soils which take plenty of water with a "second foot" flow are given a six-inch drop for the acre-length beds. A greater drop in grade than six inches is not advisable. To avoid the necessity for a greater drop, the beds should be curved or contoured within the six-inch drop grade line, until the acre-length of the bed is secured.

Amount of Irrigation Water. The amount of water to apply, and especially the length of time between applications, are determined by the nature of the season and of the soil. Some soils will absorb without injury to the crop two or three acre-inches of water in seven minutes; other types will require twice that length of time to absorb equal amounts. Hence, the length of beds between laterals, or the length of furrows and cross ditches, must be determined according to the capacity of the soil for absorption and the "head of water" available.

The normal rate of distribution and absorption for three acre-inches of water for one bed fourteen feet wide and two hundred feet long would be about seven minutes (assuming that a head of a cubic foot per second, 450 gallons, is used). If more time is required to cover the land three inches deep, the head should be increased so as to force the water over the land more rapidly. If this is not possible, the head of water may be retained and the area of application reduced. If it takes less than seven minutes to flood the land three inches deep, then the soil is taking up water very slowly and the head of water should be decreased and the water allowed to go over the land more slowly. The same end may be attained by maintaining the head of water and increasing the area to which it is being applied during a given time.

The beginner with a tract of land never before irrigated should make preliminary tests on a small scale to determine the nature of his soil with reference to these matters. Once the absorption factor is determined, it is an easy task to lay off the field in borders and beds of the proper width and length for the best results. Frequently one's neighbor who has had the same type of soil under cultivation may be able to advise with reasonable accuracy on the water requirements of new land.

After the first two irrigations of the main crop, the onions should not require too frequent waterings, if proper cultivation is maintained. However, when bulbing begins, plenty of moisture is needed. Here, too, at least ten days to two weeks should elapse between irrigations, and the amount of water given should be as light as possible for each application. It should seldom be necessary to give more than six irrigations to an onion crop, except during winter seasons of practically no rainfall. For a 300-crate-per-acre crop these six irrigations involve the use and application of about fifteen acre-inches of water. If the yield should promise to be 400 crates per acre, or in excess of that, one should probably irrigate once or twice more, using about six acre-inches more of water, or a total of about twenty-two acre-inches. The period when most of this water should be applied is usually from about the middle of February to April first, it being assumed that the crop was transplanted early in November. The second irrigation after transplanting should be given soon after the first, in order to encourage rapid new root development.

The California test for judging whether the soil may be in need of an irrigation is to take a handful of the moist soil from a few inches beneath the dry surface. If the pressed handful of earth crumbles easily, then water is necessary. In a general way it may be said that any time when the grower of a crop learns to recognize by the condition of the crop that a good rain would be immensely valuable, it is a good time to give it an irrigation. Where the border row or two-row-bed system is adopted, the same principles are involved, and irrigations and cultivations must be given to maintain an uninterrupted growth. For the border row or two-row-bed system the water applied between such rows or beds must be allowed to seep into the rows or beds without flooding the surface. That may necessitate using less water per irrigation, but making the applications at closer intervals. The one-row system will ordinarily require a greater volume of water per acre than the check and border and flood system.

Overhead System of Irrigation. In contrast to the flooding system just mentioned, some growers frequently adopt the overhead system of irrigation. The first cost of installation is expensive and varies from $150 to $300 per acre. However, once the system is installed in which galvanized pipes are used, it is of long duration. This system consists of connecting a water-main pipe line directly from the pump to the numerous smaller lateral pipe lines which ramify throughout the field. The size of the pipe is reduced to suit the distance across the field and away from the location of the pressure which is given the main pipe line. The pipe lines across the field are elevated about five to six feet high over the surface and are securely fastened to well-anchored posts. The smaller pipe lines are provided with numerous small nozzles, which are inserted at stated distances on the line. The lines across the field are situated far enough apart so that the spray when forced through the nozzles by pressure from the pump and engine will cover all the surface between in the form of a fine drizzling rain.

This system has not been generally adopted in Texas, although it may be well suited to rolling land and in sections where frost is feared during the active growing season. The crop may thus be protected through the effect of a drizzling rain as it comes out from the pipes. The overhead system of irrigation is frequently very beneficial on peat or muck soils. Here the seedlings are frequently lost as the dry peat or muck is blown away by high winds early in the spring, to the extent of uncovering and uprooting the young onion plants. The use of a small amount of water spread with the overhead system of irrigation will prevent the shifting of the soil during a wind storm and save the crop from destruction. The same is also true of sandy soils which are subject to the action of winds.

CHAPTER VII

CULTIVATION

ONIONS require intensive cultural methods, but nothing technical or difficult. It requires good judgment concerning conditions as they develop, and then close attention to the details of proper management to meet those conditions.

As soon as the shallow surface roots develop and occupy the soil, no cultivation should be deep enough to cut them. After that period the hoe should take the place of the cultivator. Hand weeding should be done at proper intervals to keep weeds out of the rows between the plants. Such weedings keep the soil mulched and prevent crusting between the plants. All things being equal, the success of the crop depends largely upon whether the grower succeeds in keeping the plant growing vigorously and continuously. Every time the plants are checked in their growth, the volume of the crop is reduced, and development of seed stems, splits, and doubles is encouraged. The soil should be cultivated towards the onions which are maturing, so as to keep them covered with a thin soil mulch. This protects them from the effects of the direct intense heat of the sun. This especially applies to the Crystal White Wax variety.

Care should be taken with all cultivation methods not to develop a compact stratum immediately beneath the surface. This frequently occurs if cultivation is given when the soil is too wet. This condition of a hardpan stratum is very dangerous and objectionable, and sooner or later must be broken, although it can rarely be accomplished without injury to the growing crop. A condition of hardpan should always be broken up in the preparation of the soil ahead of the sowing of the seeds, or of transplanting.

Horse Cultivation. With the increase in acreage planted in South Texas and during years of scarcity in labor, it is evident that serious attention must be given to a proper reduction in the cost of production.

Under the discussion of the raised rows or beds a few economy suggestions have already been given concerning the cost items (see p. 29). The level-bed and check-border system may easily be adjusted for horse cultivation by planting the rows fifteen inches apart. Instead of using the beet cultivator, which is provided with shallow sweeps for raised rows or beds, a suitable cross beam is substituted with three sets of Planet Junior or Iron Age single-wheel cultivators (minus the wheels). These frames are mounted on suitable stocks, which extend down from the cross beam. Any of the attachments of the single-wheel-hoe cultivator may then be used and cultivation carried out for three rows instead of one row at a time. Of course, any type of shaft for a single horse or mule will suit for attachment forward. A buggy shaft is about the most quickly available in most localities. In this way one man and mule could easily cultivate five to six acres per day, and do the work thoroughly. This equipment, with various changes in details, has been used by the Laredo growers in Texas for several years. The same cross beam may be equipped so that shallow sweeps may be used for the border row and raised bed borders in other districts, if it is not desirable to use the sugar-beet cultivator. When the plants get so large that they lap across the rows and too many leaves are broken with horse cultivation, the crop should be kept clean by hoeing and weeding with day laborers.

ONION CULTURE UNDER DRY FARMING

"Dry farming" onions are grown directly from the seed-drill without transplanting, and hence it is especially important that the land be free from weed seeds; neglect in this direction will otherwise raise the cost of weeding, which may easily become greater than the cost of transplanting. The land should be thoroughly prepared by plowing, discing, and leveling. Then the seed-bed is allowed to settle and become firm before sowing. After each rain the land should be harrowed to prevent crusting of the surface.

With an abundance of moisture near the surface of a firm seed-bed, the seed are to be drilled in. With a high rate of germination, and a good season in the soil, three pounds of seed drilled in evenly should give a full stand in twelve-inch rows, and not require a great amount of thinning. Unless thinned to the proper distances in the rows, the bulbs will be less uniform in size and require more careful grading. This may be offset by a saving in labor and cost of production. If seeds of highest quality as to germination be used, and then drilled to a thin stand, the loss in grades and pack through lack of uniformity is not so great. The width of rows should be gauged according to the fertility of the soil. They should be wide enough to permit of thorough horse cultivation to keep out weeds and conserve the moisture by a perfect soil mulch. Without irrigation, rows should seldom be closer than eighteen to twenty inches, and more frequently a two-foot width is advisable. The most critical period in the history of the crop is just as the young plants are pushing through the ground. Under no circumstances should a crust be allowed to form during this time. Once the small plants have their tender tops turned downward from trying to force through a crust, they seldom if ever recover and make a good vigorous profitable plant. Greater losses as to the stand are incurred at the time the small plants are forcing through the ground than many growers realize. The germination should be watched closely and a few good wheel hoes of the Planet Junior, or Iron Age type should be ready at hand. At the least indication of crusting, the rows should at once be straddled with wheel hoes, and cultivation should be deep enough to break the crust and enable the plants to push through without a check.

Care should be exercised not to cultivate too quickly after a rain; otherwise the packing of the soil, yet too wet, will result in a hardpan beneath. A good laborer should cultivate an acre of onions in twelve-inch rows per day, and a proportionately larger acreage with wider rows. If the rows are wide enough to permit the use of a mule or horse, a laborer with proper implements may easily cultivate four to six acres per day. It is important to keep up with the weeding in the rows and not to permit the weeds to become well rooted. In pulling out deep-rooted weeds, it will seriously disturb the onion roots. If thinning is necessary, it should be done early enough so that it will not disturb those which are to remain. If possible, thinning should be done when the soil is moist, then the remaining roots will be less disturbed. In thinning out to a stand, only the most vigorous plants should be left. Four inches apart in the drill will produce the most uniform size and the one most popular in the markets.

Growing the Bermuda onion by dry-farming methods in the South Texas territory where they are so successfully grown under a system of irrigation is probably not advisable on a large scale. Those localities in South Texas with loamy types of soil and well-distributed seasonal rainfall may safely dry-farm small acreages of onions. While it is not always possible to produce the greatest yield without irrigation, the onions raised by dry-farming far excel as to keeping qualities. They ripen firm and sound and are thus preferable for storage purposes.

PRODUCING A CROP OF BERMUDAS DIRECT FROM SEED

Frequently, to avoid the expense of preparing the seed-beds and then transplanting the sets to the main field, onion growers sow their Bermuda onion seeds in drills direct in the field. In this case, the land is prepared as for the seed-bed; that is, it is thrown into rows or into beds with borders. The seed are sown in drills thick enough to secure a good stand, as for dry-farming. The methods of irrigation and cultivation are exactly the same as for transplanting the crop. The advantages in this system may be enumerated as follows: (a) a saving in transplanting, (b) a deeper root system, (c) earlier maturity from time of sowing,

(d) method profitable with a late start. The disadvantages are as follows: (a) cost of thinning, (b) irregular stand, and (c) longer period of irrigation for the entire acreage. This method of direct seeding may perhaps only be recommended where extreme earliness is sought or, in cases of a late start, where the grower finds himself unable to sow the seed-bed and transplant afterward.

In the northern states the seed is sown as early in the spring as is possible. On a large scale the seed are sown by means of a gang of drills which are hitched together, and which plant from five to seven rows at a time. However, a better distribution of the seed is usually obtained by using the single-row hand drill. When hand cultivation is practiced throughout, the distance between the rows varies from twelve to fourteen inches. However, when cultivation is done by horse, this varies from twenty-four to twenty-six inches. The quantity of seed used for the northern onion varieties varies from four and a half to five pounds per acre. This is true where the rows are fourteen inches apart. However, where the rows are three feet apart, only one and a quarter to one and a half pounds of seed are used per acre. When onions are grown for pickling purposes, the amount of seed may be as much as twenty-five pounds per acre.

Propagation of Onions from Seed Versus Green Sets

In some of the northern states the onion crop is produced either by planting the seeds direct in the field and thinning them out to a stand, or in transplanting

TABLE 8

Comparison of Profits per Acre in Growing Onions from Seed and from Green Sets

Year	*Yellow Globe*						*Prize Taker*					
	Seed			*Sets*			*Seed*			*Sets*		
	Value of Crop	*Cost of Production*	*Profit*	*Value of Crop*	*Cost of Production*	*Profit*	*Value of Crop*	*Cost of Production*	*Profit*	*Value of Crop*	*Cost of Production*	*Profit*
1907	$310.10	$ 89.10	$221.00	$667.26	$177.00	$490.26	$436.74	$109.10	$327.64			
1908	212.77	104.15	108.62	240.00	176.01	63.99	221.41	107.15	114.26			
1909	341.65	104.15	237.50	541.20	159.07	382.13	275.95	103.78	172.15			
1910	242.91	93.10	149.81	422.14	167.93	254.21	295.32	113.40	181.92	$808.62	$144.95	$663.68
1911	60.13	110.20	−50.07	256.35	118.37	137.98	22.64	108.00	−85.36	350.60	108.70	241.90
1912	295.95	109.90	186.05	267.37	129.73	137.64	424.38	101.60	322.78	401.47	125.28	276.19
Six-year average	243.92	101.77	142.15	399.05	154.69	244.38	279.41	107.17	172.23			
Three-year average	......	......	......	......	......	......	247.45	107.67	139.78	520.23	126.31	393.92

TABLE 9

Comparison of Cost of Growing Onions from Seed and from Green Sets

(Average cost per acre of two varieties)

	1907		*1908*		*1909*		*1910*		*1911*		*1912*		*Average*	
	Seed	*Sets*	*Seed*	*Sets*	*Seed*	*Sets*	*Seed*	*Sets*	*Seed*	*Sets*	*Seed*	*Sets*	*Seed*	*Sets*
Manure	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00	$27.00
Preparations for planting	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Seeds or sets	10.00	75.00	7.00	69.36	7.00	55.32	6.50	41.29	6.00	15.19	8.50	31.25	7.50	47.90
Planting	1.50	21.00	1.50	27.00	1.50	18.00	1.50	19.40	1.20	24.40	1.30	24.90	1.42	22.45
Tillage	21.70	21.60	20.15	12.35	16.60	13.00	12.05	8.70	9.85	5.85	10.75	10.60	15.18	12.01
Weeding and thinning	14.80	3.90	28.50	7.80	29.85	7.80	39.00	20.75	48.15	16.60	35.85	9.50	32.69	11.06
Harvesting	19.60	24.00	17.00	28.00	17.52	33.45	12.70	34.80	12.40	20.00	17.85	19.75	16.18	26.67
Total	$99.10	$177.00	$105.65	$176.01	$103.97	$159.07	$103.25	$156.44	$109.10	$113.54	$105.75	$127.50	$104.47	$151.59

TABLE 10

Yield of Onions from Seed and from Green Sets

Year	Yellow Globe, Bushels per Acre						Prize Taker, Bushels per Acre					
	Seed			Sets			Seed			Sets		
	Large	*Small*	*Total*	*Large*	*Small*	*Total*	*Large*	*Small*	*Total*	*Large*	*Small*	*Total*
1907	413.46	......	413.46	533.81	......	533.81	582.32	......	582.32			
1908	225.44	87.37	312.81	291.23	14.04	305.27	276.49	28.07	304.56			
1909	452.77	4.14	456.91	670.46	9.65	680.11	364.18	5.61	369.79			
1910	296.92	10.74	307.66	520.91	10.81	531.72	356.56	20.14	376.70	804.77	7.72	812.49
1911	62.39	26.67	89.06	255.79	1.12	256.91	19.65	15.79	35.44	350.18	0.84	351.02
1912	491.93	2.63	494.56	444.91	1.40	446.31	706.32	1.96	708.28	668.77	0.70	669.47
Six-year average	323.82	21.92	345.74	452.85	6.17	459.02	384.25	11.93	396.18			
Three-year average	......	......	......	407.20	4.44	411.64	360.84	12.63	373.47	607.90	3.09	610.99

green sets direct from the seed-beds to the main field. The question as to which method is most profitable is apparently answered by the Illinois Experiment Station (see Table 8). From this table, it is seen that during a six-year average, there was an increase of large onions per acre in favor of transplanting green sets as compared to seed. This was true of two standard varieties tested, namely, the Yellow Globe and the Prize Taker.

As to the cost of growing onions from either seed or green sets, it is evident, as seen in Table 9, that it is a little less when they are grown from seed than when they are grown from green sets. However, with the green sets the crop is more certain; the yields are larger, and the bulbs ripen earlier. The extra cost in labor in growing green sets is more than offset by the larger profits from the increased yields. This is shown in Table 10, which is self-explanatory.

THE USE OF DRY SETS

Not infrequently, onion growers use dry sets (Fig. 4, H) for early maturity. These, if they have been previously well cured and kept dry, will start to sprout in storage the latter part of September, and in this condition they are ready for planting. These are planted in rows; the distance between the rows and the methods of irrigation and cultivation are the same as practiced for the transplanted green sets of Bermuda onions in Texas.

It is believed that onions grown from dry sets are generally lacking in keeping qualities; hence, they are grown primarily for the purpose of securing the earliest shipments of the season. This, of course, under Texas conditions at least, is done at a sacrifice in yield, because crops from dry sets produce only a poor average of lower-grade market onions. Furthermore, if the winter season is unfavorable, the yields will even be cut down to a margin below profit.

Dry sets, commonly known as "bottom sets," may include every marketable variety grown in the North or in the southern states. Large dry sets have a tendency to run to seed stems, "splits," and "doubles." The best grade to use, if they are to be used at all, should be the small bulbs, the diameter of which varies from one-quarter to one-half or five-eighths of an inch. Should the stock contain a good many large ones, they should be sorted out and planted separately. It requires eight to nine bushels of dry sets per acre. The cost varies from five to ten cents per pound including freight or express. At that rate, under southern conditions especially, dry sets would cost $1.68 to $2.24 per bushel of thirty-two pounds each, or $12.80 to $21.16 per acre for sets alone. This seems more expensive than growing seedlings for transplanting. However, if prices, as they frequently do, drop from $2.00 per bushel at the opening of the season to $1.00 in less than two weeks, one is tempted to take the risk and grow at least part of the crop from dry sets for early harvest and market.

GREEN BUNCHING ONIONS

This seems to be an established industry in the southern states where onions are profitably grown during the winter months. This is, no doubt, due to the fact that seed are frequently high-priced and too scarce to justify cutting down the main acreage, to devote part of it to bunch onions. However, growers with small acreages find it very profitable to produce green bunch onions for the market, which always absorbs large quantities. They usually use the dry sets for that purpose, planting the larger sets, and in this way they are ready for the market in about four weeks. When the smaller dry sets are used, the bunch onions will be ready for market in about six to eight weeks.

Frost Warnings

In the South, each district should arrange at the approach of the winter season to have the United States Weather Bureau Service send telegraphic warnings direct to the proper representatives, in order that all growers may be warned of the approach of a cold wave which might injure the crop.

These warnings are valuable and important. It is conceded by most growers that it is not wise to continue cultivations just ahead of or during severe cold-wave weather. Experienced growers discontinue cultivations as soon as it becomes evident that a cold wave may develop.

Onions, either in the seedling stage or in the field, will usually suffer greater injury should a severe cold wave catch them when the soil is dry and in need of irrigation. Timely warning of the approach of cold waves enables the growers, in many instances, to give that portion of their crops in greatest danger an irrigation before the cold wave actually reaches them. As a rule, all freshly cultivated crops or seed-beds should be given a light irrigation, if possible, at the approach of a cold spell. However, if such irrigation would result in an excess of moisture in the land, it would be better to take chances without it. While it is necessary to cease cultivation during cold weather, it is equally important to resume it as soon as it gets warmer. Such workings will warm the soil more quickly, and force a more satisfactory growth after the check which may have resulted from the cold wave.

CHAPTER VIII

Harvesting and Curing

In the northern states the onion crop ripens and is actually harvested during the latter part of summer and early in the autumn. In the South, Texas for instance, in which the crop is grown during the winter, the harvesting and marketing is done during the spring months, and it is practically ended before the northern product goes to the market.

In the northern onion districts the bulbs remain in the soil until the tops have fallen and partly shriveled and the outer skin has completely dried before they are pulled. On the other hand, in the southern states, where most of the onions are not housed and stored, but consumed by early markets, the bulbs are not so thoroughly matured and cured. They are pulled out about the time the tops begin to break and fall. In order to hasten the ripening process, a light roller may be passed over the plants, to kink and break down the top. The roller must not be heavy enough to bruise the bulbs in passing over them.

The first indication of ripening or the approach of maturity is recognized from feeling of the necks of the plants. If they are softening, the tops will soon begin to fall over. Should the onions begin to mature from the tips of the leaves gradually down to the neck, and the latter remain rigid and firm, an unnatural process of ripening is taking place. This may result in poor keeping and shipping qualities. A crop of onions maturing in this manner should always be marketed promptly during the harvesting period.

When the necks have softened normally, and a fourth to a third of the tops have fallen, the crop may be harvested even though the tops may yet show much green. Growers with large acreages must begin harvesting when a fifth to a fourth of the tops are down, and most of those standing have softened necks. An onion crop in that condition has made its best growth. There is always some loss in yield when most of the tops have not been permitted to fall. Owing to unevenness in the fertility of soils, one patch will drop earlier than others. Hence judgment must be exercised and the best average condition of the maturity of the crop considered. Digging at that time will involve the least loss in yield, and secure the best average keeping quality.

Bermuda onions should never be permitted to start a second growth once they are well bulbed (Fig. 2, F). If so, their keeping qualities are forever impaired, and they are then fit for immediate use only. Heavy rains with abundant warm sunshiny weather during ripening may easily induce a second growth, or may cause a crop already mature to sunscald and waterlog. Under these conditions the onions from such a crop are never safe for storage.

If the tops are very green at harvest time, the onions should remain in small windrows, and be allowed to cure before clipping (Fig. 3, D). If the weather is too hot and bright, what is called sunscalding may occur, especially in the case of Crystal Wax. Under such conditions they should be clipped promptly and left in the sun only long enough so that the earth may dry and the onions clean readily from trash or dirt; also that they may seal well at the clipped end.

Onions dug while yet too green do not easily shed the outside husks unless given time to dry and cure. Unless the onions are fairly well cleaned from the old husk, the pack does not look clean and bright and may, for that reason, sell slightly under the market, even though the bulbs are otherwise of high grade and quality. Hence, good judgment as to maturity will enable the grower to harvest onions of good shipping and keeping qualities.

Should the onions be rained on after being clipped, or after being clipped and crated, it is exceedingly important that they be first thoroughly dried before shipment. If in the field, the piles or windrows of clipped onions should be spread so as to dry quickly; if in the crates, the onions should be poured out and spread and exposed to the air to dry. Nothing will dry the onions so quickly and insure safety so cheaply as a little warm sunshine and the open air. An onion rained on after being clipped and crated and ready for market, is exceedingly treacherous, and one may easily be deceived during a sultry rainy spell. If slightly damp, the onions should be poured slowly from one crate into another in the open air and sunshine. This places the inside onions outside and dries them quickly. Onions should not be packed or stored as long as they are sappy or soft at the clipped ends.

Under Michigan conditions, where onions are grown on muck lands, the onions are not always topped in the field. They are simply thrown together into windrows, regardless of direction, in such a way that the tops partially shade the bulbs. They are thus left in the row for a few days to partially cure and then forked into crates. These crates are commonly left in the field for a short time if weather conditions permit. They are stacked in the open in such a way as to permit good air drainage. After this curing, the crates are hauled to a shed or barn where the tops are cut off either by hand or by machine. After this topping, the onions are stored in wooden sheds in open crates or bins from three to six weeks. Some growers in Michigan usually leave the crates in the wooden sheds until late in the fall, and then transfer them to winter storage just before freezing weather arrives. Frequently the onions are cured directly in the field in the following manner: the bulbs are topped and placed in crates which are piled about six layers high, and covered with boards, or other suitable protection.

Once the crop is well bulbed, and market conditions and prices justify, steps may be taken to force a more rapid ripening process. The irrigations should be less frequent, and the water applied in lesser amounts. Should rains intervene and promote a vigorous growth, this may be checked by running the cultivators and tearing loose millions of the shallow surface roots. A forced ripening process, however, is always at the expense of the yield, and the earlier prices should be enough higher than the average prices expected later to justify taking such a course. Should an excessive vegetative growth threaten to delay the beginning of the bulbing of the crop, or should rains occur just at the time bulbing begins, the surface roots may be cut by cultivation to such depth as will reasonably accomplish this result. If growth has not been too rank, merely letting the crop get slightly dry without suffering, will hasten bulbing and maturity.

A few Bermuda onion growers attempt to secure earliness by sowing the seed early, transplanting early, and doing everything early. Early seeding means the end of August. Early planting means the end of October. That means, if proper growth is secured, the crop should begin bulbing during January and February. With a crop in such advanced stage of growth, severe cold spells or severe freezes which would kill the tops would be sufficient to injure the plants beyond recovery, so far as quality and high yield are concerned. Early crops usually fail as often as they succeed, because of possible freezes.

METHOD OF HARVESTING

The crop should not be irrigated just ahead of digging time. It is the custom in the South to plow out the onions and use day labor for throwing them out on borders, in windrows, ready for the clippers.

When onions are dug too green and clipped before they have been permitted to lie in the sun for a day or two, to dry and cure, the bulbs often force out their central "bud" again, as if starting to grow. Bulbs thus affected should be closely culled out and sold locally. Well-matured onions may be clipped at once. All clipped and crated onions should be removed from the field and placed under cover as a protection against the heat of the sun. Damp or moist onions dropped into crates as clipped by the laborers, decay quickly, if they are not properly spread and dried out before assorting, packing, and loading.

The clipping is usually done by contract at the rate of two to three cents per crate. The laborers use the ordinary sheep shears with which they clip off both roots and tops, the latter being cut to about one-half-inch stubs. The onions should be clipped into piles in the open. If the necks show much sap when clipped, the bulbs should be left in the open to dry more thoroughly. This will insure better keeping quality, especially during climatic conditions which favor decay. Care must be taken during exceedingly bright, sunshiny days that the onions do not sunscald. Under such conditions a couple of hours will serve to dry the cut ends, and then the onions should be crated and crate tops placed over them. Better still, they should be hauled to the packing sheds, and graded and packed in the shade.

SHUFFLING, CLEANING, AND CRATING

Each grower's method as to cleaning the onions, once they are clipped, varies with each particular case. As stated elsewhere, the onions are usually clipped "on the ground," that is, not dropped into crates by the clippers as the bulbs are clipped. This allows the cut ends of the stems to dry and cure somewhat; also the old skins and dirt will dry more quickly and shed more easily. If the onions are quite mature and dry when dug and the weather is dry and hot, then the old husk and dirt remaining attached is at a minimum and readily sheds. If the ground is too wet when the onions are dug, then it is far better to clip on the ground, so they may dry thoroughly before being cleaned.

In order that the clippers may be given their proper credits, the crates are merely counted, if the onions have been clipped into crates. If not clipped into crates, then the grower may, and usually does, require that the onions be picked into the crates according to size and colors. In this way the ones that are off variety and color are left on the ground and later picked up separately. If the bulbs of any variety are of an even size when harvested, it is customary to require that all under two inches in diameter be left on the ground, while the sizes larger than two inches are put into crates. Then the smaller onions, or boilers, are put into separate containers. If the crop was of an even size throughout, mostly above two inches, no extra pay is given for this preliminary assorting, which in that case merely amounts to leaving out the Wax and Reds from the Yellows; or the Yellows and Reds from the Wax. If the crop is very uneven as to size or consists mostly of smaller sizes, the preliminary assorting is not practicable except as to the off colors. The onions are then crated "field run," as soon as they are dry enough for shuffling and cleaning.

If the onions are even as to size and have been assorted as indicated, the laborers pass along the rows of crated onions, shuffle them over and refill the crates with the cleaned onions. If the onions are too uneven, they are usually loaded on wagons and hauled to the central packing shed, or to a grading and cleaning table which is moved from place to place in the field. In either case the onions are shuffled by two workmen, one of whom is placed at either end of an eight- or nine-foot piece of burlap. Ducking or canvas is not suited, because the meshes are too closely woven and the sand shuffled from the onions does not pass through it. Burlap is used because the meshes are wider, hence the sand readily passes through them and the skins of the onions remain uninjured. The shuffling is done in this manner: a crate of onions is emptied onto the burlap; the two laborers then take hold of the burlap, one at each end, and raise the onions clear of the ground. One laborer holds his end high and the other low, and then the reverse is done with a twisting motion, until all onions are gently rubbed and rolled against each other, the friction loosening the old skins and dirt. If a table is used, the two workmen merely pour the onions on the screening table where others push them along. The dirt and chaff at once fall through the crevices of the screen, while the workmen further down the table do the sorting.

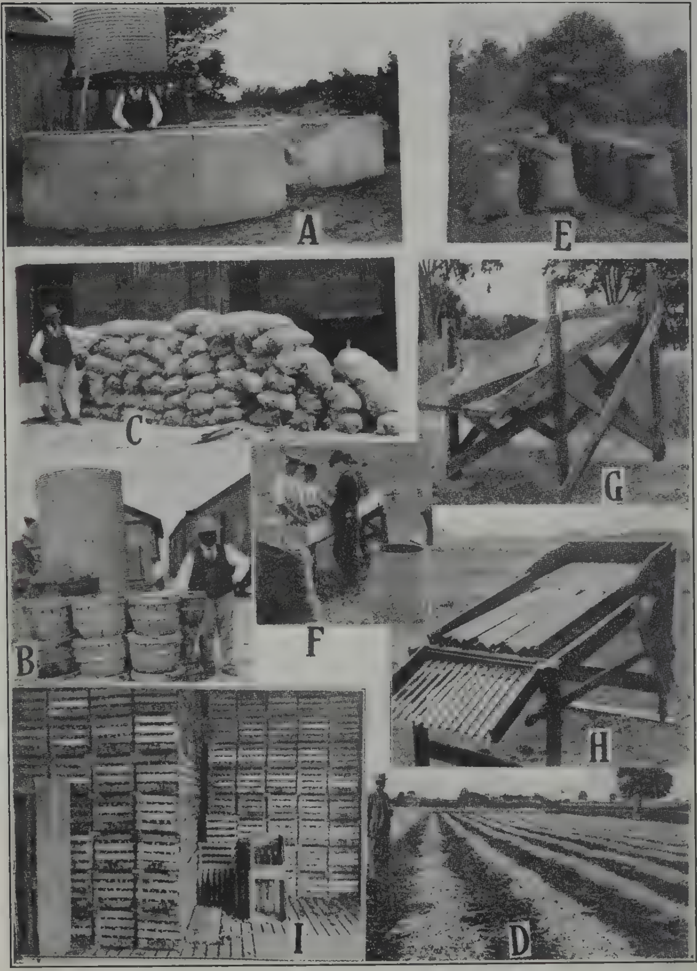

Fig. 3.

A. Galvanized tank used to dip green sets with Black Leaf 40 solution. *B*. Shipping onions in peach bushel baskets. *C*. Shipping onions in sacks. *D*. Onions curing in the windrow before topping. *E*. Curing onions in sacks in field. *F*. Grading onions in field by means of a screen. *G*. Sorting rack. *H*. Topping machine. *I*. Inside of storage house.

CHAPTER IX

GRADING

DURING the process of handling by the clippers and the filling of the crates afterwards, the onions dry enough to clean easily. Screening frames are built and the onions are poured on the floor of the upper end of one of these screens after being shuffled, as explained in the preceding section. Laborers then shove the onions down over the ribbed bottom of this screen, set on a slight incline. The shuffling has worked off the dirt and skins, most of which falls through while the onions roll on (Fig. 3, F to G). As they pass down the table, trained men at each side, and one at the end of the frame, assort the several grades. Each workman selects his grade and places it in crates beside him. If the onions clean well as they are thus handled over the screening and assorting table, they need not be shuffled before being topped. Thus treated, the onions look bright and clean in the crates and present a most inviting appearance. It enables those in charge of the marketing to secure the best possible prices.

A rather green onion will dry and cure soundly from a bruise more readily and perfectly than a ripe onion. The less onions require to be handled, the less are the chances of bruising. In grading, tables of various kinds are used. If the onions run medium to large only, a slatted bottom table is required which is built higher on one end. The slats are one inch square with two edges trimmed round. They are placed about three-fourths to seven-eighths of an inch apart. The onions are poured on this table at the high end and, are gradually worked down to the lower end, all culls being picked out and removed in the process. The best grade requires that only sound onions of one color, size, and shape be packed in one crate. All odd colors are sorted out, each color being packed in separate crates. The market definitely demands a uniform grade and a full pack.

During the marketing season of the year 1916 the Bureau of Markets of the United States Department of Agriculture coöperated with the Farm Demonstration agent in the Laredo district in making field tests and studies of all factors that go to make standards and grades for Texas Bermuda onions.

As a result of the first year's investigation, and the records of the cars inspected at loading stations and then inspected at destinations, the Bureau of Markets suggested specifications for tentative grades to be tested in the movement of the 1917 crop. The grades as proposed, for the first time in the Bermuda onion industry, recognized the principle of tolerance so generally recognized in grades of other commodities. Experience of previous years in marketing showed that too many brokers, buyers, and commission merchants were tempted to avail themselves of mere technicalities. The Bureau of Markets continued further field tests during the marketing of the 1918 onion crop, in order to ascertain what changes or additions were necessary.

One of the greatest difficulties in securing a uniform grade in the past has been to get uniformity in size for each grade. Much progress has been made along this line by the use of the Boggs' potato grader, which is really a sizer only. The onions are shuffled and cleaned over some kind of table, the lower end of which is attached to the Boggs' grader. While the laborers work the onions down from the high end of this cleaner table, all the Wax or pink onions are culled by the laborers and dropped in separate crates. The splits, doubles, and badly shaped onions are also culled and placed in separate crates. The onions then remaining are pushed over the end of the screening table into the endless chain mesh belt of the sizer. These sizers can only make the grades according to the meshes in the endless chains. One laborer turns the crank and operates the machine. The onions fall through the meshes of each chain in succession until they are caught by a mesh too small for them. Each chain drops the onions it carries to the end of the roller, and thus each size or grade drops through a chute into crates which keeps it separate from all the others.

By the use of this sizer in grading a number of cars of onions, both Wax and Yellow, it was found that the injury, if any, was no greater than by any other method of grading. The sizes are almost exact and the crates of each grade show a remarkable uniformity. By using this, or a similar sizer, all growers will be certain to secure the same grades and pack. Buyers are able to depend on the character of the grade, and can market the crop in a more satisfactory manner. For pickling onions an ordinary fanning mill is used to clean, in which special screens are provided for that purpose.

The cost of grading depends somewhat on the uniformity of the onion, its color, form, and size. If the seed is pure and each color grown separately, the grading will be less expensive. Likewise, with few "splits," "doubles," etc., the cost of grading is also minimized. Ordinarily the average grower is satisfied if the cost of the grading does not rise above two cents per crate. The following are the United States standard grades of Bermuda onions:

UNITED STATES GRADES FOR BERMUDA ONIONS

Recommended by the U. S. Department of Agriculture

U. S. Grade No. 1

U. S. No. 1 shall consist of Bermuda onions of one variety, which are mature, well shaped, free from doubles, splits, bottlenecks, seed stems and noticeably pink onions, and from damage caused by dirt or other foreign matter, moisture, sunburn, sunscald, cuts, disease, insects, or mechanical or other means. See *Size Classification.*

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by weight, of any lot may be below the requirements of this grade, but not more than one-fifth of this tolerance, or 2 per cent, may be allowed for onions which are water-soaked or affected by decay or sunscald.

U. S. Grade No. 2

U. S. No. 2 shall consist of Bermuda onions of one variety which are free from bottlenecks, seed stems, and splits, and from damage caused by moisture, sunburn, cuts, disease, insects, or mechanical or other means. Yellow Bermuda onions may show not more than 15 per cent by weight of the lot noticeably pink.

In order to allow for variations incident to proper grading and handling not more than 10 per cent by weight of any lot may be below the requirements of this grade, but not more than one-fifth of this tolerance, or 2 per cent, may be allowed for onions which are water-soaked or affected by decay or sunscald.

U. S. Grade No. 3

U. S. No. 3 shall consist of onions which do not meet the requirements of the foregoing grades.

Pink Classification

Yellow Bermuda onions showing more than 15 per cent, by weight, of the lot noticeably pink but otherwise conforming to one of the above grades shall be designated as "Pink" in addition to the statement of grade, as "U. S. No. 1 Pink" or "U. S. No. 2 Pink."

Size Classification

Onions may be classified for size on the following basis, but *unless otherwise specified shall meet the requirements of "medium."*

Small (Boilers)	Medium	Large
1 to 2 inches	2 to 3½ inches	Over 10% above 3½ inches

In order to allow for variations in sizing, not more than 5 per cent, by weight, may be below the minimum requirements, of "small," or "medium," and in addition not more than 10 per cent, by weight, may be larger than the maximum size of the class.

Definition of Terms

As used in these grades:

"One variety" means onions which have the same varietal characteristics which are all White or all Yellow, and not a mixture.

"Mature" means having reached a stage of development at which the onions are firm, not becoming soft or spongy.

"Well shaped" means having the characteristic shape, not three-, four- or five-sided, thick necked or badly pinched by hard, dry soil, but not necessarily of the flat Bermuda type.

"Doubles" means onions which have developed more than one distinct bulb joined only at the base.

"Splits" means onions which have developed more than one distinct bulb, but covered by an outer scale.

"Bottlenecks" means onions which have thick necks, usually with poorly developed bulbs.

"Seed stems" means onions in which the seed stem has become woody.

"Noticeably pink" means the pink color often found in the yellow Bermuda onions, when so conspicuous as to be readily apparent upon casual examination of the lot.

"Free from damage" means that the onions shall not be injured to an extent readily apparent under proper methods of grading.

"Sunburn" means discoloration due to exposure to the sun where there is no injury to the tissue.

"Sunscald" means softening of the tissue of the onion due to exposure to the sun.

"Diameter" means the greatest diameter at right angles to a straight line running from the stem to the root.

UNITED STATES GRADES FOR NORTHERN-GROWN ONIONS[1]

Recommended by the United States Department of Agriculture

U. S. Grade No. 1

U. S. Grade No. 1 shall consist of sound onions of similar varietal characteristics which are free from doubles, scallions, and sprouted onions and practically free from dirt, tops, or other foreign matter, and damage caused by disease, insects, or mechanical or other means. The diameter shall not be less than 1¼ inches.

In order to allow for variations incident to commercial grading and handling, 5 per cent by weight of any lot may be under the prescribed size, and in addition, 5 per cent by weight of any such lot may be below the remaining requirements of this grade.

If any lot which meets the requirements of this grade contains more than 25 per cent by weight of onions with diameters from 1¼ to 1¾ inches, inclusive, the grade name shall be "U. S. Grade No. 1, Medium."

If any lot which meets the requirements of this grade contains more than 90 per cent by weight of onions with a diameter greater than 2¼ inches the grade name shall be "U. S. Grade No. 1, Large."

U. S. Grade Boilers

U. S. Grade Boilers shall consist of sound onions of similar varietal characteristics which are free from doubles, scallions, and sprouted onions and practically free from dirt, tops or other foreign matter, and damage caused by disease, insects, or mechanical or other means. The diameter shall not be less than three-quarters of an inch nor more than $1\frac{3}{8}$ inches.

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[1] Northern-grown onions include all varieties grown in the United States except Bermudas, Denias, and Creoles.

In order to allow for variations incident to commercial grading and handling, 5 per cent by weight of any lot may vary from the prescribed size, and, in addition, 5 per cent by weight of any such lot may be below the remaining requirements of this grade.

U. S. Grade No. 2

U. S. Grade No. 2 shall consist of onions which do not meet the requirements of any of the foregoing grades.

Definition of Grade Terms

As used in these grades:

"Double" means an onion which, by splitting into two parts, has broken the outer skin.

"Scallion" means an onion which has a thick neck and a relatively small and poorly developed bulb.

"Practically free" means that the appearance shall not be injured to an extent readily apparent upon casual examination of the lot.

"Diameter" means the greatest dimension at right angles to a straight line running from the stem to the root.

CONTAINERS

There are several standard brands of crates, and all are acceptable to the markets. The standard brands of crates are the Cummer, Owossa, Madero, and the Mineola or Butcher. The Texas law on Standards for containers of vegetable crops now provides that all models of onion crates shall be of the same dimensions as to length, width, and height, the cubic contents being for a bushel of onions.

A portion of the crop each year is shipped in open mesh ventilated sacks (Fig. 3, C, and E) especially designed for the shipment of onions and potatoes. These hold an even weight of one hundred pounds.

This container is proving satisfactory for shorter-distance shipments, and to those markets further away which distribute onions largely in sacks. The far Eastern markets, however prefer or even insist on the crate (Fig. 3, I). If not the crate, then the bushel basket (Fig. 3, B) is demanded. The latter is somewhat cheaper and is well ventilated. When the baskets are properly filled and packed, carefully capped, and properly loaded in cars, they carry through to markets safely. The three forms of packages are all authorized by the Texas Standards law as well as by many other states.

MARKETS AND MARKETING

Experience has shown that in marketing we must consider (*a*) maturity of the crop; (*b*) proper grading and cleaning; (*c*) full packs in standard crates. Care with the first will insure good quality in the onion itself, besides making it a better keeper and shipper. With the three factors mentioned carefully secured, the grower may confidently expect the best price that the market will stand during any given year and under all conditions. Poor stuff may sell at a profit to a grower during a season of high price levels, but it never sells as well as high-grade stock at any time. When the grower has grade and quality, he is certain of the best price the market affords.

During the onion shipping seasons of 1916 and 1917, the Bureau of Markets, United States Department of Agriculture, established branch stations at Laredo, Mission, and Crystal City, Texas, all in the center of the Bermuda onion territory. From these offices a daily bulletin was issued, showing climatic as well as market conditions in all the greater markets throughout the United States. Each morning these offices received reports through the direct representatives of the United States Department of Agriculture in each of those leading markets. The selling price of onions in those markets was given, as well as the car arrivals, car diversions en route, cars on track, the condition, and other information of value. Under the laws, each Texas railroad is required to wire the office of the U. S. Bureau of Markets each morning, the exact number of cars that have been shipped over its line the day and night previous, and the diversions at division points. This record shows to what markets of the United States each day's shipments were going, also the markets to which, or from which, diversions were made. A complete bureau of information service was thus created by the Bureau of Markets, the value of which cannot be estimated. This has further resulted in the establishment of market news and price service in the heart of the onion belt, instead of at the eastern terminals. The growers, buyers, brokers, and sales agents meet daily at the Texas headquarters for receiving this information. Each year the result has been that a greater portion of the onion crop has been sold in Texas on a cash or bank guarantee basis than ever before.

This market news service has been invaluable because of the ability of all marketing agencies, including the growers, to avoid glutting the terminal stations at the great distributing centers. With such a complete record of the daily movement, diversions can easily be made so as to avoid overcrowding of any market.

LOADING THE CARS

Care in properly stacking and wedging the rows of crates in the cars is of great importance. It is imperative in loading that the lines of air circulation between the rows of crates be kept clear from end to end of the car. The rows should be so arranged that there is a distinct air space between the wall of the car and the adjoining row of containers. This will allow air-space lines for the six rows of crates in the car.

The rows are usually stacked three to four containers high and then bound, as explained on p. 95. If a heavily loaded car is wanted, rows are stacked four containers high and then bound. Extra heavy loading is only advisable when there is a short haul or a car shortage, or unusually cool weather conditions throughout the North; or when the harvesting season is dry and favorable and the onions are sound, mature, and dry.

The several rows of crated onions are bound by one row across the top. The first row of this is set flush against the side of the car, and each row set flush against this one, until the last one is set flush against the wall on the other side of the car. This requires eight crates in width, or eight rows through the length of the car.

The loader should be equipped with a large wooden mallet, so that as each crate is set, it may be driven up flush, end to end, keeping the rail of the crates in the clear, and each crate above is set flush on the rails of the crate below. This secures the greatest amount of air space around each crate of onions. Likewise, it is necessary, for proper ventilation, to make the loading come out even at the end of the rows or middle of the car.

The crates are set parallel, running through the length of the car. Inasmuch as cars are of uneven lengths, the exact number of crates in a row of a car will vary, and may leave fractional spaces at the ends. These spaces must be avoided and filled in by setting a few crates on ends. This avoids slipping and upsetting of containers during transit. Some loaders adjust the fractional space at the end of the car, while others do so at the middle. When the car is adjusted at the middle, the loading is started at each end and finished at the door. To "take up the slack," the crates are set on ends instead of lengthwise, and enough are set this way to make a tight row. In case of much "slack," three or four crates may need to be set on end; in case of little slack, two or three will suffice. One layer of crates is set solid across the top of this "key" or "tie," from wall to wall, the same as for binding the ends of the cars. The top layer in the middle tie is usually about half the length of the crate higher than the top layer from each end. Figure 3 illustrates the loading as discussed. If the loading is carefully done, nothing short of a wreck will prevent the car from reaching its destination in proper condition.

REFRIGERATOR CARS

Any good type of refrigerator car is used in shipping onions. It is important that all such cars have their plugs out and vents open. This specification should be stamped on each bill of lading. The most perfect ventilation is very necessary in order that the onions do not decay in transit. During years of car shortage, box cars, with vents and wings cut in both ends of the car, have proven satisfactory in furnishing the necessary ventilation.

The size of refrigerating car ordinarily furnished will load 468 to 472 crates. Other sizes may have room enough for 482, 494, and even 502 crates, or more. When onions are dried and well cured, this quantity is not dangerous. During a hot rainy or damp digging season the loads should run to the lesser quantities—about 464 crates per car. During dry digging seasons the loading may safely run to 600 or even 700 crates per car. For the heavy loading, seven rows of crates are stacked through the cars, with four high and the tie across. For the 500-crate cars six rows are run four high with a tie. When onions are damp, the car should not contain over six rows, three high, with a tie.

CHAPTER X

THE DRY KILN, THE DEHYDRATOR, AND DRIED ONIONS

A METHOD of dry-kilning Bermuda onions for storage is now in process of development. As already explained, the Bermuda onion must be thoroughly cured and sealed before it can have perfect keeping or storage qualities. This curing may be hastened by artificial means by adapting the ordinary sweet potato curing house for this purpose. This may be done by providing a drum and burner for heating and drying the air. It should also be equipped with a power fan for drawing the heated air through the stacks of crated onions, and exhausting the air charged with the moisture from the bulbs through flues or ventilators above and below the stacks of crates. Tests carried on by the authors have indicated that the air within the house may be dried and heated to a temperature of 120° F. without injury to the onions. For success, it is imperative that the air be kept moving, and that dry air take the place of the moistened air. When this is accomplished through the installation of a power fan to move the air quickly enough, the temperature need not be maintained much over 100° F. unless it is desired to hasten the process of drying. If it is desired to dry out damp onions quickly for loading, the time required is of much importance. The heat of the air may be adjusted through the burner, so that not less than an hour nor more than two to three hours may be required.

This treatment should greatly improve the keeping qualities of the onions in transit. Should a rainy spell catch the grower with a great quantity of onions, either clipped and on the ground, or crated and in the field, it is very important that they be first thoroughly dried before attempting to ship them. Further tests indicate that even though the onions are dripping wet when placed on the drying screens, they are dried and cured and made reasonably safe for shipment in a few hours by the process outlined above and which is now being perfected to try out on a commercial scale.

The dry-kiln process quickly develops the symptoms of either decay or sunscald or waterlogging. These defective onions may therefore be discarded at the final grading, and enable the grower to ship only sound onions. The dry-kiln process also checks or prevents the development of the black mold which is likely to appear on onions which are slightly damp when loaded, even though they appear sound when they are shipped to the market. The crates which are to be stacked in the kiln or drying house should not be over half-full of onions. Otherwise, those in the middle may not be fully dry, when those on the outside may be dried sufficiently.

By the installation of a home dryer equipment along with the home canning outfits usually found in each community, the culls or off onions may be converted into a wholesome, sanitary, and profitable product, and often a great waste saved. The onions which are cut and bruised when being plowed, and those that are culls, or off-shaped, or off-color, may be properly cleaned and sliced, and then dried and packed in proper

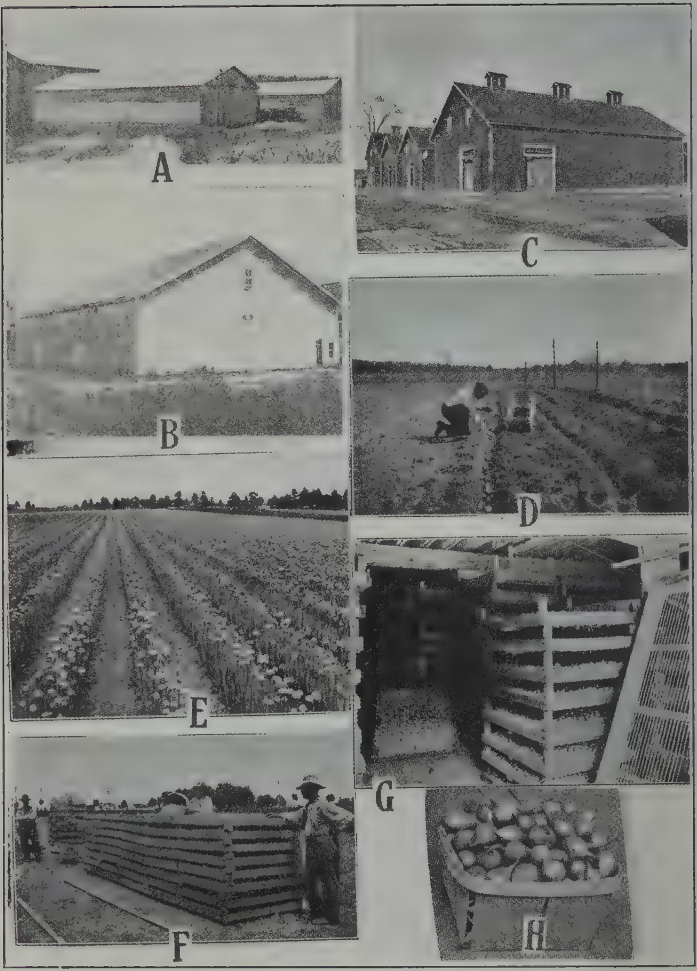

FIG. 4.

A. Curing sheds where onions are stored after topping to finish curing, and before entering the storage house for the winter months. *B*. A good type of onion storage house used in Michigan (*A* and *B*, after C. P. Halligan). *C*. Onion store houses. *D*. Method of setting out bulbs for seed production. *E*. Field of onion seed before harvesting. *F*. Onion sets drying on trays piled in a field. *G*. Onion sets stored in trays in a warehouse. *H*. A quart of ideal sized dry onion sets. (*C* to *H*, after W. R. Beattie.)

cartons, in the same manner as other vegetables are prepared and dried, by this process.

STORAGE

It has already been shown that many diseases of the bulbs are favored by poor storage conditions. Proper storage is, therefore, of greatest importance especially as it concerns onions grown in the northern states, in which the bulbs are stored during the winter months before they are put on the market. Poorly ripened onions will not keep well in storage. This will exclude immature, soft, or thick necks. Good storage onions will be well cured in the field and will rattle like blocks of wood when poured from one crate to another. After the bulbs have gone through the preliminary curing in open sheds for a period of several weeks, they are then screened and removed to the storage house. It is customary to screen onions each time they are moved, because in this way all loose skins and decayed bulbs are removed and sorted out. Onions should never be permitted to remain in the open so that they will be injured through freezing.

The essentials of proper storage conditions are: plenty of ventilation, storing in small quantity, a comparatively low temperature, dryness, and safety from actual freezing. Any building which will answer these conditions may be used as a safe house for storing onions. In building a storage house for onions (Fig. 4, B and C), it should be double throughout with plenty of felt or paper lining, and containing plenty of top and bottom ventilation. These ventilators should be so arranged that they may be opened or closed at will, depending on temperature. The floors are constructed of narrow planks, with half-inch spaces between the planks for the passage of air. Bottom ventilation is frequently secured by means of drain pipes built into the foundation at the surface of the ground. These pipes are carried some distance to the center of the house and discharge cool air at the point where it is most needed. The temperature of the storage house should be carried as low as possible without actual freezing. During extremely cold weather in some of the northern states, the ventilator openings and doors should be kept closed to keep out cold air. It is usually advisable to have the onions chilled but not frozen. A low temperature should be maintained. During excessively cold weather, a little artificial heat from a stove or radiator may be necessary. Onions will be safe as long as the temperature does not fall below 23° F. A temperature of 34° to 36° F. will give best results.

Attempts have frequently been made to store Bermuda onions, with little success. However, there is no reason why Bermuda onions could not be successfully stored, especially on a small scale. The essential factors are of course low temperature—say about 34° F. after the onions have been properly cured in the field or shed. Such a temperature may be had by some system of refrigeration or artificial fanning, the method of which is still to be perfected. Likewise, the method of utilizing the sweet potato dry-kiln for kiln-drying, as indicated on p. 97, offers considerable promise for perfecting a successful method for Bermuda onion storage in the South.

Onions (other than Bermudas) are frequently stored in standard slatted crates 20 inches long, 16 inches wide, and 14 inches deep outside measurements. They are also frequently stored in slatted bins holding 100 to 300 bushels each. They are, likewise, stored in bags, but crates seem to be preferred.

Bermuda onions which are to be stored for some time should be dug just as they are fully grown, but not fully mature or ripe. A really ripe Bermuda onion has poor keeping qualities. For storage they should be plowed out just as a considerable portion of the necks are soft, but while the tops are green. They should be thrown in windrows and left a couple of days for the tops to wilt, and to cure and become sealed at their necks. Dug at such a stage of maturity they have proven to possess far greater keeping qualities than do fully mature or ripe onions.

The husks of onions attract or draw moisture. A damp air is therefore much against the storage, especially of the Bermuda onion. When taken from the fields, the onions should be well cured and dried.

COST OF PRODUCTION

No one should begin with the Bermuda onion as a cash crop unless he has the necessary land and irrigation facilities or ample capital to rent a properly equipped irrigation property. Furthermore, before launching out in the production of Bermuda onions, one should be fully advised of every phase of the industry. The crop is grown a long distance from the markets, the product is perishable, and it is only consumed at certain times of the year. The following is a conservative estimate of cost of production of Bermuda onions in Texas:

Acre Cost of Production and Harvesting

Seed, 3 lbs. Wax, $2.50 per lb.; yellow, $1.75	$ 5.25 to $7.50
Preparing land, plowing, discing, leveling, and bordering	7.25 to 9.00
Transplanting, including cost of pulling of seedlings and delivery to planters	12.00 to 15.00
Cost of irrigation (pumping and cost of applications)	15.00 to 25.00
Weeding	3.50 to 5.50
Cost of cultivation	7.00 to 9.00
Cost of growing onion crops per acre	$50.00 to 71.00
Harvesting, grading, and hauling 6 to 10 cents per crate, 300 crates per acre	18.00 to 30.00
300 crates at 20 cents each	60.00 to 60.00
	$128.00 to 161.00
If the grower has rented, then add $25.00 per acre rent	25.00 to 25.00
	$153.00 to 186.00
If fertilizer is used add $30.00 per acre	30.00 to 30.00
Total cost per acre on rented land	$183.00 to 216.00
If the grower be the owner, then add $12.00 per acre for interest, taxes, and repairs to power plant per acre, to the cost of the onions crated	128.00 to 161.00
Interest, etc.	12.00 to 12.00
	$140.00 to 173.00
If fertilizer is used, add $30.00 per acre	30.00 to 30.00
	$170.00 to 203.00

Hence on the basis assumed, of producing a 300-crate-per-acre crop, and the maximum and minimum cost per acre to the tenant of $183 and $216 per acre, the price must be at least 65 cents net per crate, and more often 75 cents per crate net, before the tenant grower has a safe margin of profit. If the grower is the land owner he would not be safe at less than 58 cents per crate net on board the cars, and more often it would need to be 68 cents. If the crop is raised without rent and fertilizer, then a 300-crate-per-acre crop may be put on board cars at 45 cents to 55 cents per crate.

COST ITEMS OF HARVESTING, GRADING, ETC.

A grower within a mile of a loading switch may reasonably expect to put his crop on the cars at about the following cost items:

	Cents	
Plowing out the onions	½ to ¾	per crate
Clipping the onions	3 to 5	"
Grading, including hauling to grader, and cleating of crates	1 to 2	"
Hauling to cars	1 to 1	"
Loading at cars	¼ to ½	"
Total cost of harvesting	5¾ to 9¼	"

No expense was prorated for account of the manager. From the above data it is found in practice that the short-haul grower rarely harvests the crop and puts it on the cars at less than 6 to 10 cents per crate. Those who have to haul in excess of a mile have a proportionately higher f.o.b. cost. With a 300-crate-per-acre crop, it is evident that the grower needs working capital, or credit for a short time, at the rate of $54 to $67.50 per acre to harvest the crop and put it on the cars.

TOOLS AND IMPLEMENTS

No unusual tools are required. Good reversible disc plows and disc harrows are needed. There are several forms of smoothing harrows from which selections may be made. A good disc cultivator or a celery hiller (Fig. 2, A) is needed for marking and throwing up borders. A good supply of head and ditch gates, as well as ditch stops and boxes for dividing or diverting the water, will be most needed. For hand cultivation the complete equipment of either the Planet Junior or Iron Age garden implements (Fig. 1, D) are satisfactory.

For smoothing and pulverizing through horse cultivation the Meeker harrow is indispensable. The fourteen-tooth harrow is always useful. For most of the horse cultivation a sugar-beet cultivator, having each of the stocks mounted with a four-inch sweep, will answer the purpose. Installing grading machines to be operated either by hand or motor power should be attended in ample time ahead of the rush of the season.

At harvest time sheep shears for clipping, and grading tables for cleaning and assorting the onions should be on hand. A Fresno grader is one of the most useful implements on any irrigated farm, and its frequent use at any leisure time on vacant lands, keeps them well leveled and graded and ready for most economical operation.

CHAPTER XI

Home Production of Onion Seed

Until quite recently most of the seed of the Bermuda varieties were grown and imported from the Canary Islands from Teneriffe; the White Bermuda seed cost about $1.50 to $1.75 per pound, while the Crystal Wax seed are seldom less than $2.00 to $2.50 per pound. Recently, however, thousands of pounds of onion seed have been produced in California and shipped to Texas, and to the many other southern states where the Bermuda varieties are grown extensively. The California-grown seed are delivered earlier than the imported. As to the northern-grown varieties of onions, many of the leading growers in a number of the northern states are raising their own supply of seed. In this way they perhaps produce a better grade than it is possible to buy on the general market.

As long as onions were produced on a small scale, a number of growers produced their own supply of seed from carefully selected standard types of bulbs. In commercial onion seed growing where the bulbs are raised exclusively for seed purposes, such great care in selection has not been practiced.

In Michigan good crops of seed are produced on muck lands, although the best seed is really obtained on upland hills. The production of onion seed is, however, not restricted to any one soil or locality, but can usually be produced wherever the onion crop is grown profitably.

STAGES IN THE PRODUCTION OF ONION SEED

Selection and Care of Bulbs

The "mother bulbs" are the mature bulbs which are used for the production of onion seed. These are grown in the same way as is practiced for the general crop for market, requiring somewhat more care at certain stages. Instead of using four pounds of seed per acre as is ordinarily practiced in the commercial onion centers, seedsmen here prefer to use six pounds of seed per acre, so as to force the bulbs to crowd and remain rather small. These mother bulbs are cared for and harvested in the same manner as are first-class marketable stock. Immediately after the bulbs are mature the first summer season, they are dried and stored over winter under good storage conditions. The following spring they are taken out from the storage house, the bulbs carefully culled, and the sound ones planted again in the field (Fig. 4, D) for the production of a seed crop. In selecting the mother bulbs for seed planting, we should have in mind the form, color, and the general characteristics which we desire to perpetuate in our strain. Ordinarily two selections are made: One in which a small number of the very best bulbs are picked and these used as stock for seed to be used the following year for the growing of the seed bulbs. The second selection includes the bulbs from which to grow the supply of seed for next year's market. Usually bulbs varying from one and a half inches to two inches in diameter are preferred for seed production. The soil on which onion seed are produced should be rich, containing plenty of humus and moisture. A good rich sandy loam is preferred. No fresh stable manure should ever be used where bulbs for seed are planted. Commercial fertilizer is advisable only when it contains a small percentage of nitrogen, six to eight per cent of available phosphoric acid, and six to eight per cent of potash applied at the rate of 1000 pounds per acre. Before the mother bulbs are set out, the fertilizer should first be incorporated in the soil and the land properly prepared to a state of tilth. The land is then marked off at intervals of 2 to 3½ feet, a one-horse plow or a corn-marker being used, or any implement which will leave a decided furrow in which to set the bulbs. The mother bulbs are then planted by hand, root downward, and spaced about three to six inches, center to center, in the furrow. The quantity of mother bulbs used per acre will depend on the size. Usually, it requires about 250 bushels. As growth begins and proceeds, the soil is thrown around the bulb to form a support to the seed stalks. Cultivation should be shallow and frequent so as to keep the soil well worked and free from weeds.

The proper time to gather the seed stalks (Fig. 4, E) is when the inside of the seed has reached the dough stage. Onion seeds turn black-colored even before they have passed the water stage and form milk in the seed. The change of color, therefore, does not indicate ripening and for this reason many inexperienced growers have been deceived. The heads should be harvested before the first-formed seed begin to shatter in handling. When the seed stalks are cut, they should be brought into a building with a tile floor which has plenty of free circulation of air. Frequently growers employ buildings (Fig. 4, A) for curing the onion seed, such as are used for tobacco. The seed heads are thus placed in wire bottom racks or trays stacked one above the other (Fig. 4, F and G). The seed are then stirred from time to time during the curing process. The most important thing to remember is not to pile up the seed heads very thickly. The layers should not be over two heads in depth. Plenty of ventilation and frequent stirring of the seed heads is necessary. In the northern states the time for gathering the seed heads will depend upon the locality and the climate, being generally about midsummer or not later than August fifteenth. The thrashing and cleaning of the seed may be carried out considerably later or at any time in the autumn. When seed are produced on a large acreage, the thrashing is done with a thrashing machine similar to regular grain thrashers. However, when the seed are grown on a small scale, they are removed by beating with a flail. In order that the seed may be protected from heating or molding, they are run through a fanning mill so as to remove all chaff and dust. After this fanning and cleaning, they are spread out again rather thinly on the floor on a canvas and stirred from time to time.

The amount of seed obtained will depend on the kind of mother bulbs previously used. Ordinarily in localities in which overgrown sets are used, ten to twelve pounds of seed are obtained to the bushel of sets planted. Such seed, however, should not be used for producing the main crop, but only for seed-growing, or pickling onions. Where standard, carefully selected mother bulbs are used, three to four pounds of seed are obtained for every bushel of bulbs planted.

Three and one-half pounds of seed is considered a satisfactory average. This will make about 400 pounds per acre, although in some rare instances 800 to 1000 pounds of seed have been secured per acre.

Production of Seed for Onion-set Growing

Frequently the seed for onion-set growing are produced from bulbs selected from the sets themselves, a practice which means overgrown bulbs. In Kentucky, growers of onion sets usually prefer seed grown from the over-sized bulbs, which they store during the winter. During the spring these bulbs are distributed to farmers in the hill country and are planted on bluegrass land which has been heavily manured. In this way the onion seed are produced free from disease, and possess a higher vitality than would be the case if the seed were grown on the same land where the bulbs were originally produced. When the mother bulbs are selected for seed and onion-set production, they should be well matured, uniform in size, small-necked, and have good shape.

Care of Onion Seed

Onion seed usually lose their vitality in a short time. This is largely influenced by climatic conditions and the maturity of the seed. Usually onion seeds lose their viability the second year, especially if stored in a damp climate. Many of the seedsmen, therefore, ship their onion seed for storage into drier climates.

PRODUCTION OF DRY ONION SETS

The term "dry set" means a small, undersized bulb (Fig. 4, H), which when replanted in the ground will produce a large onion. This is perhaps the earliest method of producing the onion crop. The quickest way of producing dry sets is to sow a large quantity of seed on a small area of rich land and in this way obtain a large number of small, undersized bulbs—a condition which is brought about by thick sowing, overcrowding, and lack of plant food. In the United States dry onion sets are mostly produced near Louisville, Kentucky; Chillicothe, Ohio; Chicago, Illinois; in the Platte River Valley of Nebraska; in southwest New Jersey; and in southern California. The yield per acre of dry onion sets is about 300 bushels. The amount of seed required varies from 60 to 80 or 100 pounds per acre; the seed are planted in twelve-inch rows. The sets are harvested when the necks begin to turn soft and while the tops are still green and mostly erect. The sets are then pulled by hand, dropped into bushel baskets or containers, hauled to sheds, emptied into shallow-slatted crates, and stacked for storing and curing. If too much dirt and trash has been pulled with the small sets, they should be screened somewhat before stacking. When properly cured, they are topped and graded. The ideal size of a dry set has a diameter of one-half to three-quarters of an inch. The smaller sets, when used for the main crop, produce less "splits" and "doubles" than is the case when the larger-sized bulbs are used.

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Part II

DISEASES AND INSECT PESTS

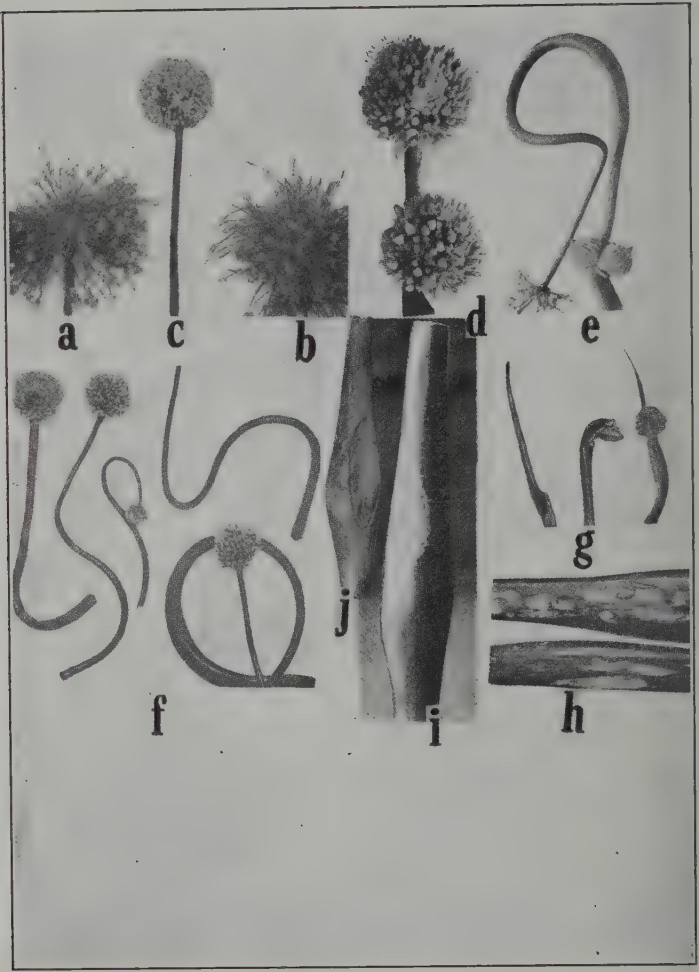

FIG. 5.

a and *b*. Bastard blossoms. *c*. Normal blossom. *d*. Double head. *e*. Bulblet head. *f*. Goose neck. *g*. Elongated spathe. *h*. Hail injury. *i*. Early stage of white ring disease. *j*. Same as *i*, but more advanced stage, showing sinking of spot. (*a* to *h*, after G. P. Clinton; *i* and *j* after C. W. Edgerton).

Part II

DISEASES

CHAPTER XII

Troubles Not Due to Parasites

Bastard Blossom. This is a common name applied to abnormal heads which are often met with in the field. Here the individual pedicels are more elongated than the heads; so the flowers seem to spread out in a large loose way. It is often claimed that such deformed heads produce little or no seed. This sterility, as stated by Clinton, is due to the fact that the pistils are often changed into leafy structures. Sometimes the heads fail to form blossoms altogether, and in its place numerous slender stem-like growths are developed from little bulbils (Fig. 5, A, B, and C).

Bulblet Head. Sometimes, instead of producing a normal cluster of blossoms at the end of the stalk, the plant forms a branch of bulblets, as is often the case in wild species of Alium (Fig. 5, E).

Double Flower Head. Instead of a normal single flower cluster on the end of the stem, there may often appear two, a lateral one below the other. Both clusters may be of the same size and the distance between the two may vary (Fig. 5, D).

Elongated Spathe. Under normal conditions and when young, the onion flowerhead is enclosed by a small spathe, which later breaks and withers at the side as a sort of bract. Occasionally, however, this remains permanent and pretentious, thus continuing as a pointed extension of the stem, which the blossoms finally force to one side (Fig. 5, G).

Gooseneck. This term is applied to a malformation which appears as crooks in the stem of the flower head. These crooks may develop all the way from a slight bend to a complete coil. The natural tendency, however, after the bending has become prominent, is for the tip to start growth upward, resulting in half turns and bends. The exact cause of this condition is not known (Fig. 5, F).

Hail Injury. Hail injury is quite a common occurrence in some states. The symptoms of the trouble do not differ from a similar injury on other crops, namely, white spots or marks on the side of the stalks from which the storm came. The seriousness of the injury, of course, depends on the size of the hail stone and on the rapidity of its fall (Fig. 5, H).

White Ring. This trouble is usually indicated as narrow white rings or cracks around the stem. These begin as small breaks in the epidermis which extends crosswise. These rings may be single or many and parallel to each other and may occur on the lower part of the stem. If these rings extend deeply into the tissue affected, stems may break over. This trouble is apparently not due to insect injury, but the result of growth cracks. In this case, the epidermis of the rapidly growing stem is very thick, and this results in an unusual stretching and ends in cracks which develop at the place of greatest strain, which appears to be above the bulbs or the stems.

Onion Brittle. This disease was reported from Connecticut in a 100-acre onion-field affected by this trouble. The disease seems to spread from year to year, especially where onions are grown too long on the same land.

Diseased leaves become brittle, and curl up in a peculiar fashion. In advanced cases diseased leaves form regular spiral coils. The brittle effect on the foliage seems to be a secondary manifestation. The primary cause probably resides in the roots. Onion plants affected by brittle disease show a peculiar swelling of the tips of the roots; which differs from the swelling caused by root knot. A Fusarium fungus seems to be prevalent in the tissue of the swellings; however, the parasitism of this organism has not as yet been demonstrated. As a remedial measure, crop rotation is recommended.

False Blight. Wherever plants are suffering from pink root or from extreme drouth, heat, or thrip injury, the tender tips of the rapidly growing onion leaves are sometimes inclined to wither and to die gradually from the top downward. This withering gives the plant the appearance of blight greatly resembling the downy mildew (*Peronospora schleideniana*). Such leaves wither, turn white, and dry up. The term "blight," therefore, in this case is misleading, because this trouble seems to be of no parasitic origin. The trouble becomes apparent at least in some of the southern states when the plants suffer from lack of moisture and are suddenly supplied with an abundance of water. This is especially true in the irrigated districts. Attacks from onion thrips will reduce the vigor of the plants, thus checking the growth and resulting in the premature dying of the tips of the foliage. Badly diseased plants suffering from pink root and hence equally lacking in vigor will often manifest the symptoms of the false blight just mentioned. Not infrequently the dried-up foliage becomes covered with a number of various fungi, chief of which may be mentioned *Macrosporium parasiticum* Thuem. and *Macrosporium porri* Ell.

White Spot. This trouble is reported by Edgerton on onions in Louisiana. This is probably different from the "white ring" disease which is prevalent in Connecticut. The white spot disease first appears as yellowish dots on the enlarged portions of the onion stem, a little above the surface of the ground. These spots are usually circular in outline, gradually enlarging in size and becoming perfectly white in color (Fig. 5, I and J). As the season advances, these spots usually become covered by a varied mycological flora. The cause of the white spot disease is not known.

Splitting and Cracking. When wet weather follows a prolonged drought during the bulbing season the mature onions may split at the plate (Fig. 10, H). This condition is generally due to new and uneven growth of the affected bulbs.

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CHAPTER XIII

SOFT ROT

Caused by *Bacillus carotovorus* Jones

SOFT rot of onions is causing heavy losses practically every year. A large part of the injury occurs in transit and has been reported from various market inspectors. The disease is known to occur in the following states: California, Florida, Colorado, Illinois, Iowa, Kentucky, Louisiana, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New York, Ohio, Pennsylvania, Texas, Virginia and Washington. It seems that the Spanish onions are more susceptible to this form of decay than other varieties.

Symptoms. With diseased onions, the tissue turns glassy, that is, water-soaked in appearance, later becoming soft, watery, and developing a characteristic offensive odor. Infection commonly occurs through breaks in the scales, or through the neck, even before the crop is harvested. Usually the disease is confined to the outer two bulb scales, in which case there is a lack of firmness in the bulb when pressed between the fingers. At other times infection begins in the center of the bulb, in which case there is nothing to indicate outwardly the presence of the disease within (Fig. 6, I and J). Frequently the contributing factors to infection may be sunburn and freezing, as well as careless handling in the field or in storage.

The organism, *Bacillus carotovorus,* consists of short rods or long chains, the form depending on the age of the culture. The rods are rounded at both ends, and when properly stained will show two to ten peritrichiate flagella (Fig. 6, L). It is gram negative, produces no spores or capsules. Besides the onion, *B. carotovorus* attacks a large number of vegetables, chief of which should be mentioned: cabbage, cauliflower, turnip, carrot, potato, Jerusalem artichoke, rhubarb, tomato, and parsnip. Infection in every case is due to a wound.

Control. Since the soft rot organism can only gain entrance to the bulb through a bruise or a crack, every precaution should be taken not to injure the onions during cultivation at the growing season, or during harvesting. Care should be taken that the implements used to cultivate the crop should not be brought too near the bulbs to cause injury, nor should the bulbs be injured with implements used in digging, clipping, or grading. The onions should also be well cured before entering storage so that the neck end will be well dried and offer no opening for the causal organism to enter there. Soft rot is, perhaps, more serious in transit than it is in storage (see page 213).

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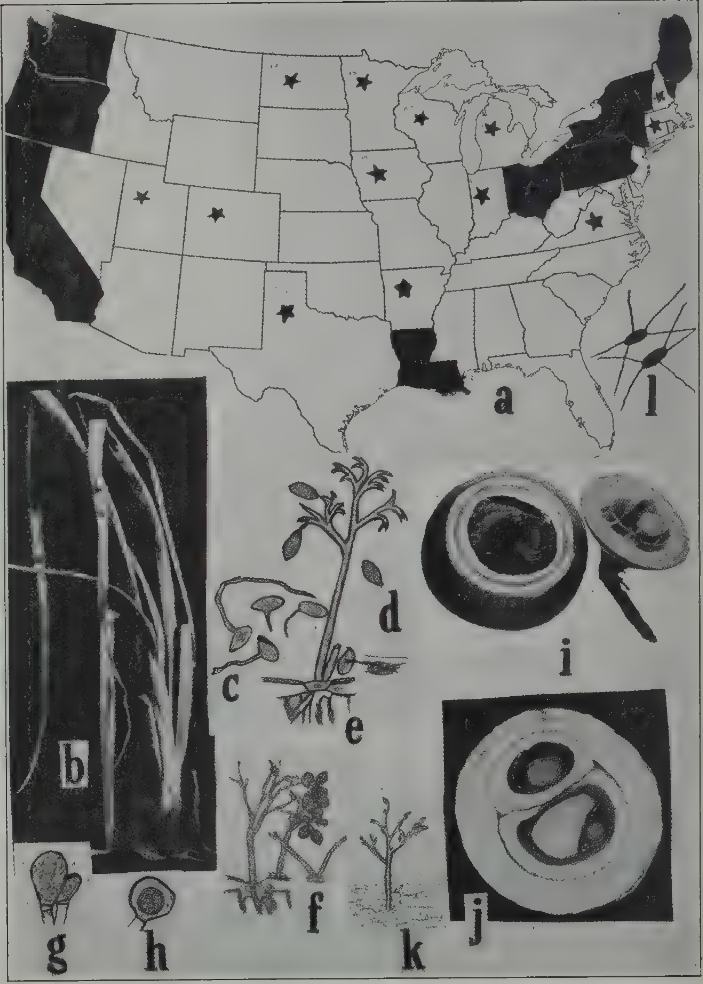

FIG. 6.

a. Distribution of downy mildew in the United States. States marked in black indicate prevalent distribution, those with star, rare or doubtful presence. *b*. Downy mildew injury to onion plant. *c*. Germinating conidia. *d*. Mature conidia. *e*. Conidiophore and conidia of *Peronospora schleideniana*. *f*. Same as *e*. *g*. Oogonium and antheribum of *P. schleideniana* at time of fertilization. *h*. Mature oospore. *k*. Same as *e*. *i* and *j*. Bacterial soft rot, rot confined to center of onion bulb. *l*. Individual rods of *B. carotovorus*. (*a*, courtesy of *U. S. Plant Disease Survey;* *b* to *h*, *k*, after H. H. Whetzel; *i*, courtesy of A. D. Selby; *j* after Stewart.)

DOWNY MILDEW (BLIGHT)

Caused by *Peronospora schleideniana* (Ung.) De By.

Next to smut (see p. 136), downy mildew is certainly a serious field disease. Fortunately, as in the case of smut, the cause of the trouble has been well worked out, and methods of control are generally known.

Distribution and Economic Importance. The disease has a wide distribution (Fig. 6, A), but is most prevalent and destructive in New York State, causing a loss of twenty to fifty per cent in some years. Frequently, however, it appears late in the season when it causes comparatively little damage. In 1903 it appeared in epidemic form. In California the disease seems to be prevalent in the onion seed farms. The damage there is slight, as the disease seems to occur only during the early spring. It is seldom if ever serious on field onions. In 1918 it was very severe on seed onions in Santa Barbara County. In Vermont downy mildew is prevalent, but not very important inasmuch as the trouble is restricted to a few vicinities where onions are grown more or less intensively. It is doubtful whether it is found in Colorado. In Ohio downy mildew is very prevalent and is found in Clermont County, where the loss is estimated at about one per cent, amounting to about $1,500 in 1906. Furthermore, the disease is quite prevalent and serious on low muck lands, and it is favored by moist cool weather. In Washington it seems to be local, being confined to the western portion of the state. There the disease ordinarily occurs late in the season, when it does practically little or no damage. If it happens to appear early in the season, the damage is appreciable. In Wisconsin downy mildew is occasionally found, but ordinarily it is of little economic importance. The same is perhaps true of Iowa, Virginia, Utah, Maine, New Hampshire, and Oregon. In Louisiana the disease is quite common, and the losses are considerable. In Pennsylvania it is said to be prevalent in practically every field, although no estimates of damages are available. The disease was also reported from Texas in 1914. It is doubtful, however, whether this was downy mildew, because the disease is probably not present in that state. The trouble might have been mistaken for tip burn, which is very common and which often follows injury from thrips or pink root.

Symptoms. Since the disease often attacks the tops of the plants at about the time that the bulbs are ready to be harvested, the average grower believes that this early dying is due to the natural ripening. For this reason, downy mildew is frequently overlooked and mistaken for other troubles. The disease usually starts during wet weather, late in June or July, on a few plants in scattered parts of the field. The best time to examine the field would be early in the morning when the plants are still wet with dew. At this stage diseased plants may be readily detected, even at a distance. When an infected leaf is examined, it will appear to have a peculiar violet color, due to the presence of the fruiting bodies of the causal fungus. These stand out very plainly because of the downy appearance that the moisture gives the affected part; hence the name, downy mildew. Later in the day, as the plants dry up on account of the sun or wind, it becomes more difficult to distinguish a diseased plant in the field. During the second day of infection diseased plants begin to lose their bright color, becoming pale or even yellowish in spots. By the third or fourth day, the affected plant has collapsed or fallen over (Fig. 6, B). After several days the affected onions seem to recover slowly, and new leaves appear which take the place of the dead ones which are drying up. If the weather is favorable, the new growth is rapid, and in a week the affected field may appear as thrifty and healthy as though it had never been struck by the mildew. In this case, however, the blight does not disappear from the field, but remains dormant, reappearing with the first favorable wet weather. From this it is plain that if the first attack appears late in the season, the onions will very likely never recover. If wet weather conditions remain for a long time, the causal fungus will attack the new growth as fast as it is formed, in which case the losses are greatest, in the sense that with the destruction of the top growth the bulbs will have no chance whatsoever of developing into marketable size. Ordinarily, there is little or no increase in the size of the bulb after a severe infection. If the attack comes after the bulbs are half formed, it simply means a loss of one-half of the crop.

The Fungus. The causal fungus of downy mildew was first named and described by Berkeley in 1841 as *Botrytis destructor.* In 1847 Unger described it as *Peronospora schleideni.* Later De Bary in 1863 changed the name to *Peronospora schleideniana* (Ung.) De By. This name has been most used in literature and is retained in the present work.

Peronospora schleideniana has two distinct fruiting stages: the one is known as conidial or summer stage spores; the other, as the sexual or resting stage, which helps the parasite to carry over from year to year. The conidia or summer spores are borne on erect branched threads which resemble trees standing out from the leaf (Fig. 6, E, F, and K). The tip ends of these branches bear the conidia, which are egg-shaped (Fig. 6, D). The fungus threads of the causal organism penetrate the leaf tissue, winding their way about among the cells, into which they send in smaller short branches (suckers or haustoria, as they are commonly known) which help to absorb the sap of the plant for food for the fungus. It is fortunate that the conidia or summer spores are short-lived and lose their germinating power very quickly. Nevertheless and in spite of this, large quantities of these spores are produced during wet weather, so that in twenty-four hours whole fields may become infected through these conidia, which are blown about by the wind or splashed about by rainwater. The sexual or resting spores, also known as oogonium, are usually formed as globose bodies scattered through the tissue of diseased leaves. The oogonium (Fig. 6, H) is the result of the sexual fusion of two definite threads, one known as the antheridium or male element, and the other the oogonium or female element (Fig. 6, G). The sexual threads come close together and the whole content of the antheridium, which contains the fertilizing sperm, is emptied into the oogonium. The contents of both now fuse, become dense, and result in the fertilized oospore or egg. It is this oospore, formed in a somewhat complicated manner, which carries the fungus over winter. The oospores are formed in great numbers in the dead and dried-up leaves. During the winter the dead leaves readily break up through decay, thus liberating the oospores which are ready to start anew the life history of the causal fungus. The oospores, under favorable conditions, are capable of germinating and of directly infecting young onion plants, thus giving rise again to infections.

It is generally agreed that warm, damp weather, with continuous rain or heavy dews, is most favorable for the spread of downy mildew. In fact, such weather conditions are usually conducive to epidemics of onion blight. Furthermore, onions on low lands with poor drainage are more susceptible to this disease than those grown on high, well-drained lands. The more exposed the onion field is to air currents and sunlight, the less damage there may be from blight. Likewise, it is desirable to keep the fields free from weeds, as otherwise these weeds tend to shade the onion plants and favor infection.

Methods of Control. Because of the rapid spread of onion blight, it is imperative in the states where the disease is very prevalent that the grower should make haste in adapting measures to prevent its rapid spread. Investigations by Whetzel have shown that the grower has two alternatives: the first is to check the disease after it has once started; and the second is to prevent its starting altogether. Experience has taught that it is far easier to prevent its introduction than to attempt to eradicate the disease once it obtains a good foothold in any given field. It has already been stated (page 123) that a second growth may usually take place after a previous severe infection. If the attack comes early enough in the season, this second growth will do much in helping to produce a normal yield. It is, therefore, imperative to protect this new growth from reinfection. This is done by spraying with a standard Bordeaux mixture. Sometimes one application will not accomplish the desired effect. In that case, the plants should be watched closely, and spraying continued twice or three times if necessary until the disease is checked.

It is far safer for the onion grower not to take any chances and to protect his crop from any possible appearance of onion blight. To do this, it is necessary that the onions be sprayed early, and that the spraying be continued throughout the season, the number of applications depending on wet weather conditions. Ordinarily, it should be given at about two- or three-week intervals.

The spraying will not do much good unless it is applied thoroughly, covering every side of the leaf; furthermore, the mixture should be applied with force through a good nozzle. The strength of Bordeaux mixture used should be a 4-4-50 formula, that is, Bordeaux made up of four pounds of copper sulphate (also known as bluestone), four pounds of fresh, unslaked lime, and fifty gallons of water.

In regard to soil conditions, only such fields should be chosen for onions as are high and well-drained. Swampy lands surrounded by high hills are especially unfavorable for onion growing in districts where downy mildew is prevalent. Tall weeds along ditches or anywhere in the field should be cut out. This will insure a free movement of air which will prove detrimental to the blight fungus.

Since the oospores are formed in the dead leaves, it is necessary that these should be raked off and destroyed by fire, or if this is not practical, they should be plowed under very deep. It is believed that the oospore may live in the soil for two or three years. In this case, a three-year rotation is strongly recommended. It appears that the red varieties are slightly less susceptible to blight than the white varieties. Ordinarily, there is little danger of introducing downy mildew with the onion seed, provided the latter is clean and free from bits of onion leaves or scales.

Preparation of Bordeaux Mixture. In states where downy mildew is prevalent, spraying with Bordeaux is recommended. It should be remembered in this connection that the Bordeaux, as a rule, will not stick well to the onion foliage. For this reason resin fish-oil soap should be added to the spray mixture, which will help make it more adhesive. The spray should always be applied thoroughly, every part of the leaf being carefully covered. The best men should be put to do the work. It should be remembered that spraying is only a form of insurance; hence the application should always be given before blight, or any other foliage disease, becomes really serious.

The following formula is used in preparing Bordeaux mixture for onion diseases:

Copper sulphate (also known as bluestone)....	4 lbs.
Quicklime..................................	4 "
Resin fish-oil soap........................	3 "
Water......................................	to make 50 gals.

Where large quantities of Bordeaux are used, it is more convenient to prepare stock solutions or suspensions, since these can be kept a long time on hand and the water lost through evaporation may be readily replaced.

Making of the Stock Solution. It is best to prepare the stock solution near a well or any other place where water is easily accessible. The barrels to hold the stock solution are placed on an elevated platform and in one of the barrels 50 pounds of copper sulphate is tied in a burlap or loose-woven sack and suspended in 50 gallons of water. At the same time and in another barrel, 50 pounds of fresh, unslaked lime is slaked and diluted in 50 gallons of water. Both the lime and the copper sulphate when properly dissolved are kept separately and are considered stock solutions. As to the resin fish-oil soap, 37½ pounds of this is put in a barrel containing 37½ gallons of water. This is stirred gradually and constantly to avoid formation of lumps. The stirring is continued until all the resin fish-oil soap is dissolved. This, too, is a stock solution. Each of the three stock solutions will contain one pound of the respective ingredients to each gallon of water.

Preparation of the Mixture. The following are directions to make 100 gallons of spray mixture. Where smaller quantities are made up at one time, the quantities used are adjusted accordingly. Two fifty-gallon barrels are provided with one head removed from each and with openings of sufficient size near the bottom head. The flow from these openings may be controlled by attaching to them a pipe nipple, pieces of ½- or 2-inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. The concentrated solutions are thoroughly stirred. Into one barrel, eight gallons of copper sulphate stock solution is measured out and into the other eight gallons of the lime suspension. To each barrel is now added enough water to make forty-seven gallons, thoroughly stirred. A trough is now provided which leads under the openings of the two barrels and rests in the strainer of the spray tank. The free ends of both pieces of hose are now lowered so that the diluted lime suspension and copper sulphate solution flow at equal rates, mixing in the trough before entering the spray tank. While the mixture is flowing into the spray tank, six gallons of the resin fish-oil soap suspension is slowly added, being poured into the spray tank strainer in a small stream. In this way the six gallons will be well distributed throughout the entire mixture. The soap suspension should not come in contact with either the lime or the copper sulphate solutions until they have been mixed. This method as given by Walker, no doubt, yields a thorough mixture of all the ingredients without necessitating hand stirring.

Neither the copper sulphate solution nor the Bordeaux mixture should ever be prepared in tin or iron vessels. Only wooden or copper containers should be used. The strainer should be of copper or bronze wire of eighteen meshes per inch. As soon as the Bordeaux is prepared, it should be used fresh, as it is not good after sitting.

The kind of spray machine (Fig. 2, H and I) to use will, of course, depend on the individual. There are a good many on the market, and every grower should study his own situation and conditions carefully before deciding which spray machine to adopt. It should be remembered in this connection that the best is the cheapest; that the thing required is strong power and the best kind of nozzle which produces the finest mist. One hundred pounds or more per square inch is considered good pressure for spraying onions.

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CHAPTER XIV

SMUDGE (BLACK SPOT OR ANTHRACNOSE)

Caused by *Cleisthothecopsis circinans* Stevens
Volutella circinans (Berk.)

SMUDGE or anthracnose usually begins as a field trouble starting just before harvest time and later continuing to develop in storage and in transit. It appears that only the white varieties are susceptible while the yellow and red varieties are immune.

Distribution and Economic Importance. It seems that smudge is confined largely and is of greater economic importance in those states in the East and Northeast rather than in the West and South. The disease is perhaps severest in Illinois, where it was closely studied by Stevens. In New York it is quite prevalent, but apparently causes little damage. In Ohio it is quite common, but the injury from it is rather slight. In Maryland it seems to be generally distributed, especially in Dorcestershire County. In Louisiana it is not uncommon, but it seems to appear in the fall when it causes very slight damage. In Minnesota it is present, but found in restricted areas, where it causes but little damage. It is also found in Texas, where it is practically of little economic importance, since few or no onions are put in storage. In Wisconsin it seems to be quite generally distributed and attacks the white varieties, especially the young sets, causing a loss of about seventy-five per cent of the seed crop during some years. In Indiana the disease was introduced quite recently and is now found in North Madison and Jefferson, La Porte, Lake and Tippecanoe counties. In Massachusetts it seems to be common, but causes little damage. In Pennsylvania, Delaware, and New Jersey it seems to be quite prevalent on white onions, but it is of no economic importance (Fig. 7, D).

Symptoms. It seems that smudge or anthracnose assumes three distinct types. The first type is known as bulb spot. This stage is the most typical of the disease and generally occurs on the dry outer scales of the onion. These spots are circular and average the size of a dime or a quarter. The color of the spot is generally black, due to the black mycelium within the tissue. The mycelium appears as numerous black knots grouped in a series of concentric circles (Fig. 7, E). While this seems to be the standard, yet there are variations from the typical concentric arrangement. Frequently the direction of the mycelium is at right angles to the main veins, appearing as transverse black bands. At other times, the arrangement of the mycelium appears as minute specks. Occasionally, these specks are fused, giving the spot an entirely black appearance. Likewise, the spots tend to follow the length of the veins. At any rate, all of the phases of the first type appear on the outer dry scales of the onion bulb. The second smudge type generally occurs on the outer dry scales of the bulbs, with the exception, however, that here the spots seem to be limited to the upper part of the bulb. At any rate, it always seems to start there and progresses to the base. This type may assume any of the variations mentioned under the first type. It is probable that the second type invariably begins with infection as the tops of the bulbs are removed. The third type is found mostly on the scales of the bulbs which are still green and succulent and remain so for a considerable time after infection has taken place. In this case, therefore, the third type may originate directly in spots formed on the outer scales. The chief characteristics of spots in the third type are development of tubercles or fungus warts (Fig. 7, F and G). These are usually formed at the centers of the spots, whether the latter are small or large in area. In older or large spots, secondary series of tubercles are often formed and occasionally in roughly concentric arrangement. There seems no question but that the three types just described are caused by the same fungus.

It has already been stated that infection usually starts in the field. The chief damage results when the onions are put in storage, and then the disease certainly becomes serious if the weather is rainy during harvesting.

The Fungus. The cause of smudge has been attributed to a fungus which has been named *Colletotrichum circinans* or *Vermicularia circinans.* Walker believes that the fungus belongs more in the Volutella group rather than the Colletotrichum or Vermicularia, because the fruiting body is more of an Acervulus and not a Pycnidium as first described by Berkeley. Walker also believes that the onion fungus closely resembles *Volutella fructi.* S. and H., an organism which causes a fruit rot of apples. Stevens in his work has determined the presence of a perithecial or ascus or winter stage. This places the causal fungus in the genus Cleistothecopsis. If this work is correct, and there seems no doubt about it, the smudge fungus has two fruiting stages, one the summer, or Volutella stage, and the other the winter or Cleistothecopsis stage. In the Volutella stage, the sporodochia (Fig. 7, F and G) are formed in concentric circles, usually in the centers of infected areas. The mycelium of the spot is hyaline at first, becoming dark and coarse with age. The setæ are numerous, scattered, and dark brown to black, usually tapering to the apex. The conidiophores are straight, single, and hyaline; a few are sometimes septate. The conidia are acute at each end, hyaline and one-celled.

The structure of the perithecia (Fig. 7, B) are irregular, globular, dark brown to black, with occasional short hairs growing on the surface. The perithecia are either formed within or on the outside of the host, and distinctly connected with the Volutella stage. Young perithecia resemble sclerotia. The ascus spores are dark and have several transverse septa (Fig. 7, C).

Control. Since the development of smudge largely depends on moisture conditions, it is imperative that every care be exercised in handling the white varieties during digging time. The onions should be dug as carefully as possible without unnecessary bruising; they should be harvested during dry weather, if this is possible, and the bulbs should not be exposed to rain. Before being placed in storage, the onions should be stacked in an open shed so as to facilitate thorough curing. In the storage house the white sets or bulbs should be placed in thin layers in shallow crates. During some years, however, when the rainfall is abnormally high, the method of curing in shallow crates stacked in the field, or in an open shed, has been generally found inadequate. Artificial drying of the sets

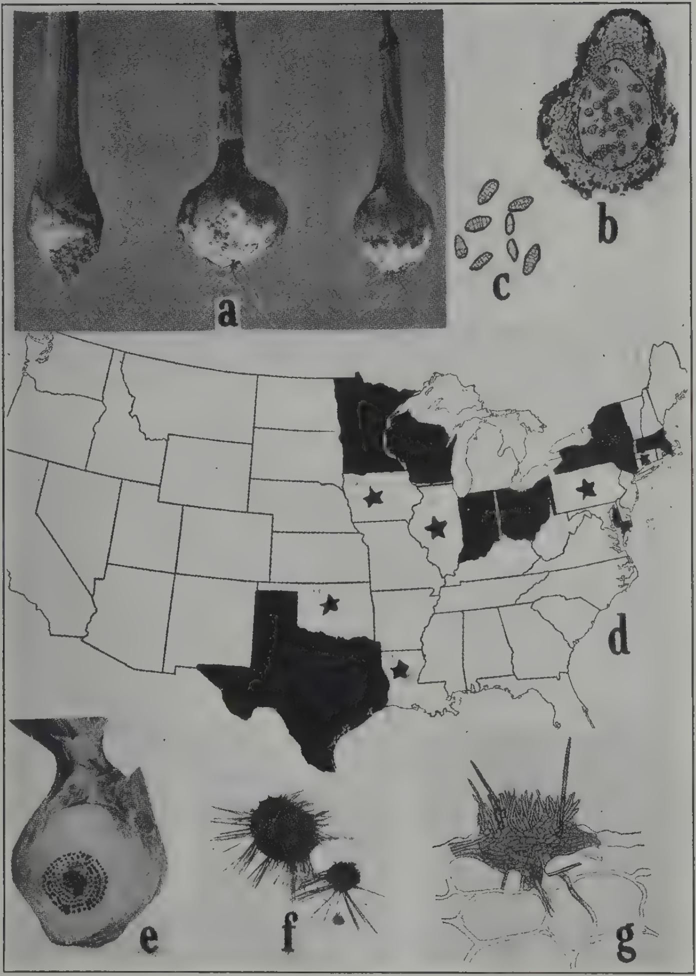

FIG. 7.

a. White mold (after A. D. Cotton). *b.* Mature perithecium with ascospores of the smudge fungus. *c.* Free ascospores. *d.* Map of United States showing distribution of smudge. *e.* Smudge of onion, showing concentric rings in spot. *f.* Photomicograph of sporodochia. *g.* Cross-section through young sporodochium, showing conidiophores and conidia. (*b*, *c*, *e* and *f* after F. L. Stevens; *d*, courtesy of *U. S. Plant Disease Survey*. *g* after J. C. Walker.)

in rooms properly equipped for this purpose appears the only method of solving the smudge problem. This disease, like the black mold described on page 165, depends on moisture conditions for development, and the sooner an artificial system of curing onions is worked out, the sooner will we succeed in reducing the losses from these two rots to a minimum, and insure a better shipping article.

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CHAPTER XV

SMUT

Caused by *Urocystis cepulae Frost.*

Of the many onion diseases, few perhaps can compare in importance to smut in the northern onion sections from New York to Oregon. This trouble has attracted attention as early as 1869, mention of which is found in the *Report of the Massachusetts State Board of Agriculture, 1860–70.* It is also mentioned in the *Report of the United States Commission of Agriculture for 1869–72.* Again, in 1876, it was mentioned by Farlow in the *Annual Report of the Massachusetts Board of Agriculture for 1876–77,* and also in the "Abstract of Returns by the Agricultural Societies of Massachusetts." In these articles, Farlow describes the fungus, for the first time, as *Urocystis cepulae* Frost, from specimens sent to him by C. C. Frost, of Brattleboro, Vermont.

In 1877, Professor Farlow considers *Urocystis cepulae* as identical with a form found on a species of wild onion (*Allium magicum*) and previously named *Urocystis magica* Pass. Likewise, and in the same year (1877), M. C. Cooke in *Gardener's Chronicle* refers to the American onion fungus as being a variety of a species *Urocystis colchici,* found in Europe on Colchicum, and thus named the American fungus *Urocystis colchici,* variety *cepulae.*

In 1879 Maxime Cornu records for the first time the appearance of *Urocystis cepulae* on onions in the neighborhood of Paris, and believes it to be identical with the American smut. In this connection, it is very likely that the species which is referred to as *Urocystis colchici* as occurring on onions in southern France in 1877 was probably the same as *Urocystis cepulae.* In 1881 the true onion smut was found in Rouen, France. From what has been stated it seems very probable that the onion smut found in France is similar to or the same as the onion smut of the United States. However, this same disease is, apparently, of little importance in France, perhaps because of differences in soil temperatures and because the gardeners there always transplant their onion seedlings and unconsciously select healthy plants. Finally, in 1880 *Urocystis cepulae* was recorded on onions near Leipsic, Germany.

From the above account it seems very likely that onion smut first originated in Europe, despite the fact that American scientists were the first to observe it and point out its economic importance. Whatever its origin, it is safe to assume that the onion smut first originated on species of wild onions and only attacked the cultivated varieties after many years of adaptation. This is supported by the assumption that *Urocystis magica* and *U. colchici* found on wild onions in Europe are botanically identical with the smut of cultivated onions, *Urocystis cepulae.*

Economic Importance. That smut of onions is of great economic importance in some parts of the United States needs no argument. It has been estimated that the disease, wherever present and under favorable weather conditions, reduces the yields five to fifty per cent. One peculiarity of this disease is that it may be extremely troublesome in some sections and yet be entirely absent in other sections of the same state. In New York State, for instance, smut is very troublesome in Orange County, while wholly absent in Madison County. The severity of the disease seldom becomes noticeable until onions have been grown on the same land for several years in succession. Under such conditions, smut increases from year to year until it becomes so destructive that onions can no longer be grown with profit. According to the *Plant Disease Bulletin,* Supplement 2, May 30, 1919, the highest loss from smut that year was reported from New York, resulting in a reduction of fifteen per cent in yield of marketable onions. In the Wallkill Valley onion section of New York it was found that the extent of injury ranged from the entire killing of the plants to a smutting of the base of the outer leaves only. Likewise, in Massachusetts the losses were estimated at two per cent, although in local instances it was as high as twenty-five per cent in some fields. In some parts of Burlington County, New Jersey, the losses from onion smut were estimated at fifty per cent. Likewise, in Pennsylvania, Wisconsin, and Oregon, estimates of losses vary from forty to ninety per cent during certain years. At Racine, Wisconsin, untreated fields showed an average of thirty-five per cent smutted plants. In 1917 estimates showed that the losses in Ohio ranged from fifteen to twenty per cent in infected fields; in Illinois, ten to fifteen per cent; in Oregon, ten per cent.

Distribution. Although the disease was first recorded in Connecticut by both Farlow and Thaxter, smut has now a very wide distribution (Fig. 8, A). It is found in practically all the northern states where onions are grown. It is difficult to determine just how the disease has gained such a wide distribution. It is probable that this is due to the use of diseased sets which were shipped from state to state without hindrance. From data furnished the writers by the Plant Disease Survey, smut is known to occur in the following states: In Alabama, smut was reported in 1917 in the onion-producing centers on the Gulf Coast. It is doubtful, however, whether the disease is of any economic importance there. In Arizona it was reported from Phœnix, but it is doubtful whether smut is of any serious consequence there. In California it is not definitely known whether or not smut occurs. In Connecticut smut is found in practically all the important onion districts to the extent that in 1917 onion-growing was decidedly on the decline. In Indiana the disease is reported from Hudson and Lake counties near the Illinois line. In Iowa it is particularly serious in the Pleasant Valley onion district, and in Clinton, Allamakee, Cerro Gordo, Linn, Story, Polk, Scott, and to a less extent in other counties. In Massachusetts the greatest damage is reported from Franklin, Hampshire, and Hampden counties; it is also prevalent in the Connecticut River Valley and the Boston district. It is found in the other important onion districts, but without very serious results; the formaldehyde treatment is extensively practiced. In New Jersey onion smut is prevalent in Warren and Burlington counties. In New York it is prevalent in Madison County in the vicinity of Canastota; also in Orange County, as well as in Monroe County. Likewise, it is prevalent in Seneca, Ontario, and Genesee counties. It is also very prevalent in the black meadows along the Wallkill Valley and in the onion regions of Wayne, Madison, and Livingston counties. In Oregon smut is reported from Marion and Washington counties, as well as in Yamhill and in the Willamette Valley; it is also becoming very serious in the onion sections of the northwest part of the state. In Ohio it is known to occur in Chillicothe, Berea, Lake, Cuyahoga, Ross, Lorain, Medina, Trumbull, Summit, Wayne, Sandusky, Wood, Van Wert, Ashtabula and Champaign counties. In Pennsylvania smut is prevalent in Erie, Columbia, Lycoming, Berks, Lancaster, and Luzerne counties. In Tennessee the disease seems to be local, especially in Knox County, where it causes but little damage. In Texas smut was reported in 1915 in Tarrant County. It is, however, exceedingly doubtful whether the disease at that time was correctly diagnosed. It is practically safe to state that onion smut does not occur in Texas. In Wisconsin it is fairly prevalent in Racine and Kenosha counties. It is also found to a limited extent in other sections of the state.

In this connection it will be noticed that smut has not been reported from Minnesota, Montana, North and South Dakota, Nebraska, Kansas, Missouri, Arkansas, Mississippi, Georgia, South Carolina, North Carolina, Virginia, West Virginia, Florida, Oklahoma, New Mexico, Wyoming, Idaho, Utah and Nevada. In referring to Fig. 8, A, one will see that onion smut is practically confined to the northern states from New York to Oregon. As clearly shown by the investigations of Walker, onion smut is limited by soil temperatures, and this is presumably why it is conspicuous by its absence in some of the southern states, such as Louisiana and Texas.

Symptoms.—Onion smut has clearly defined char-

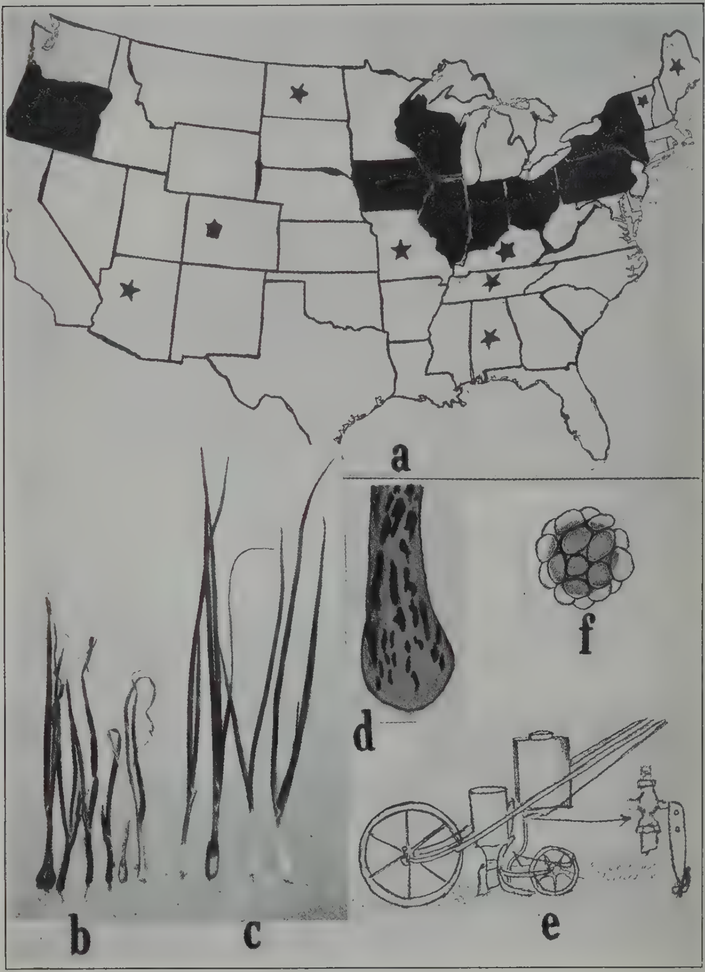

FIG. 8.

a. Occurrence of onion smut in the United States. *b*. Young onion sets affected by smut. *c*. Healthy sets. *d*. Young bulb showing unbroken blisters on scales and leaves. *e*. Seeder equipped with drip attachment. *f*. Spore ball of *Urocystis cepulae*. (*a*, courtesy of *Plant Disease Survey*, U. S. Dept. of Agr.; *b* and *c* by Professor Selby; *d* after J. C. Walker; *e* after R. E. Vaughn, and J. C. Walker; *f* after Pammel.)

acteristics and when once recognized can not be mistaken for other troubles. The disease appears at a very early age, that is, soon after the seedlings come through the ground. It is indicated as elongated blisters, either black or brown, scattered on the scales or leaves (Fig. 8, B, C, and D). Infected leaves become slightly thickened and curved downwards. Very frequently diseased leaves split open, exposing a black powder, which consists of the spores of the causal fungus. Since infection starts very early, many of the young seedlings usually die within two to five weeks after germination. Other plants seem to survive until late in the season or even until harvesting. In these cases every new leaf and scale as it develops may become infected. Diseased plants when surviving remain dwarfed, the bulbs seldom attaining marketable size. Such bulbs when closely examined will be found to be covered with brown-to-black slightly raised pustules near the base of the bulb, and infection in this case frequently occurs as deep as the third or fourth layer of the scales. A lack of sufficient moisture in the soil will frequently cause the early death of infected seedlings. On the other hand, an abundance of soil moisture will undoubtedly have a tendency to increase the resistance of the onion plant, so that the disease will apparently only keep pace with the growing host. Diseased bulbs when brought in storage will usually rot, not as a result of the smut, but on account of the invasion of other parasitic or semi-parasitic organisms. In other words, the true onion smut as far as is known is only a field disease and not a storage trouble. Onion smut first appears in the field as isolated spots here and there. These spots spread in all directions until the whole field becomes involved, and onion growing therein is thus made impossible or unprofitable.

How Smut is Spread. It should be emphasized that seed[1] onions are not attacked by smut; hence the seed are not commonly carriers of the disease. It is, however, probable that some smut spores may be lodged on the seed in diseased fields; in which case there is a great probability that the seed indirectly carry the disease as spores which may cling to the exterior seed coat. Proper care in gathering and handling the seed may, however, obviate the danger of infecting the same.

Perhaps the commonest ways in which smut is spread about are as follows: It may be spread through implements such as plows, harrows, weeders, rakes, etc., these implements carrying the smut spores with adhering particles of dirt from diseased fields. Furthermore, smut may be spread about through the adherence of particles of smutted earth to the feet of men and farm animals. Likewise smut spores may be carried about by rainwater as it washes down from the higher to the lower fields. Finally, onion smut may also be carried from field to field as spores blown about by the wind on dust particles. It is, further, likely that insects are carriers of the smut spores, and also that the disease is introduced into new fields when smutted onions unfit for market are dumped out as refuse, or in the manure pile.

Effect of Soil Temperature on Smut Prevalence. Work by Walker at the Wisconsin Experiment Station has clearly shown that there is a definite relation between environment and smut infection. It seems that soil moisture prevents field infection only at very high and very low extremes, in which case germination and growth of the host are equally retarded. It is, in reality, soil temperature which has the greatest influence. It was found, for instance, that onion seeds germinate and growth occurs at soil temperatures of about 10° to 31° C. Best top growth occurs at a soil temperature of 20° C. Seed smut infection seems most likely to occur at 10° to 25° C. At 29° C. the result is complete inhibition of infection. If infection has occurred at lower temperatures, the disease will be checked by the temperature suddenly rising to 29° C. or more. This is shown in Tables 11 to 13, by J. C. Walker and L. R. Jones.

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[1] By seed is meant here the true seed resulting from pollination of blossoms and not of the dry sets.

High air temperatures alone, even at 30° to 33° C., do not entirely prevent smut development, provided the soil temperature is below 25° C., a condition which very often prevails out-of-doors. It seems, therefore, evident that soil temperature alone is the controlling factor. The reason, perhaps, why onion smut is so common in the northern and eastern states is that onions are planted in the spring in cool soil, a condition which is not prevalent in the South, where onions are planted late in the summer under high soil temperatures.

Botanical Considerations of the Smut Fungus. Most of our knowledge on the smut fungus is due to the brilliant investigations of Professor Thaxter. The onion smut organism is a true smut and belongs to the family Ustilagineae, the latter of which contains numerous species, all of which are parasitic on various plants. The fungus which causes the smut of onions belongs to the genus Urocystis, so named because of the fact that the spores are furnished with bladder-like appendages (Fig. 8, F). The spore itself is dark, thin-walled, nearly spherical, and surrounded by a variable number of these bladder-like bodies, botanically known as pseudo-spores or false spores. These are thinner, and the walls are more transparent. Each particle of smut is, therefore, known as a "spore-ball"; hence when the smut pustules on the leaf or scale burst open, the black powder consists only of "spore-balls" such as have been described above. With *Urocystis cepulae,* there is only one resting-spore in each "spore-ball"; this resting-spore being thick-walled and surrounded by a variable number of pseudo-spores, prob-

TABLE 11

Relation of Soil Temperature to Infection of Onion Seedlings by Urocystis cepulae

Experiment 1			*Experiment 2*		
Naturally infected soil. Begun May 3, 1919, completed May 30, 1919. Records not kept as to soil moisture nor as to air conditions.			*Artificially inoculated soil. Begun Dec. 10, 1919, completed Jan. 6, 1920. Soil moisture held at 22% or two-thirds the water-holding capacity. Air temperature 13° to 25° C., relative humidity 45% to 75%*		
Soil Temperature	*Total Number of Plants*	*Smutted Plants*	*Soil Temperature*	*Total Number of Plants*	*Smutted Plants*
° C.		*Per cent*	*° C.*		*Per cent*
10 to 13	25	72	10 to 14	64	98
18 to 20	5[1]	80	16.5 to 18	49	98
22 to 24	6[1]	100	19 to 22	63	100
25 to 30	47	15	23 to 26	56	93
28 to 34	25	0	27 to 29	52	8
			29 to 31	36	0

[1] Stand reduced by damping-off fungi.

ably as many as twenty. These are regular in shape and size, nearly spherical and flattened on the side by which they adhere to the resting-spore. According to Thaxter, it is seldom that the "spore-ball" consists of two resting-spores.

TABLE 12

Relation of Soil Temperature to Infection of Onion Seedlings by Urocystis cepulae

Experiment 3			*Experiment 4*		
Naturally infected soil. Begun Dec. 20, 1919, completed Jan. 10, 1920. Soil moisture held at 25% or two-thirds the water-holding capacity. Air temperature, 13° to 25° C., relative humidity, 45% to 75%			*Artificially inoculated soil. Begun Dec. 18, 1919, completed Jan. 12, 1920. Soil moisture held at 13% or two-thirds the water-holding capacity. Air temperature, 13° to 25° C., relative humidity, 45% to 75%*		
Soil Temperature	*Total Number of Plants*	*Smutted Plants*	*Soil Temperature*	*Total Number of Plants*	*Smutted Plants*
° C.		*Per cent*	*° C.*		*Per cent*
19 to 22	44	93			
23 to 26	131	96	23 to 26	50	98
26 to 27	100	57	26 to 28	58	12
27 to 28	86	12	29 to 31	40	0

The vegetative (mycelium) part of the smut fungus consists of slender fungus threads which find their way between the cells of the affected parts of the leaf or bulb scales. The "spore-balls" or spore pustules really originated from the mycelium, that is, the resting-spore originates as a short lateral branch from a thread, and the pseudo-spores originate from other branches which grow out and surround it.

As soon as the "spore-ball" is matured, it seems to pass through a period of rest. This is evidenced by the fact that freshly borne "spore-balls" refuse to germinate in water or in moist atmosphere. These spores apparently must pass through a rest of at least a winter season. In germinating, the central resting-spore produces a simple, stout, short hyphæ, at the tip of which is formed a mass of sporidia. These secondary spores, or "spore-balls," germinate readily in water, and infection of the host takes place with the entering of the germinated sporidia into the tissue of the host.

TABLE 13

Relation of Soil Temperature to Infection of Onion Seedlings by Urocystis cepulae

Experiment 5			*Experiment 6*		
Naturally infected soil. Begun Jan. 16, 1920, completed Feb. 10, 1920. Soil moisture held at 25% or two-thirds the water-holding capacity. Air temperature, 13° to 25° C., relative humidity, 40% to 80%			*Artificially inoculated soil. Begun Jan. 16, 1920, completed Feb. 10, 1920. Soil moisture held at 15% or two-thirds the water holding capacity. Air temperature, 13° to 25° C., relative humidity, 40% to 80%*		
Soil Temperature	*Total Number of Plants*	*Smutted Plants*	*Soil Temperature*	*Total Number of Plants*	*Smutted Plants*
° C.		*Per cent*	*° C.*		*Per cent*
25 to 26	80	100	25 to 26	106	90
27 to 28	103	47	27 to 28	98	8
29 to 30.5	77	0	29 to 30.5	47	0
30 to 32	43	0	30 to 32	30	0

Manner of Infection. From this brief description of the general structure of the smut fungus, one can easily conceive how infection takes place. It has already been stated that when the resting-spore germinates, it produces secondary spores known as sporidia. It is these sporidia, when germinating, that penetrate the host. Once within the tissue, the fungus threads branch and extend themselves within, ultimately producing the typical smut pustules (Fig. 8, D). Infection of the onion takes place only in the seedling stage in the ground. This generally occurs immediately after germination of the seed and just before the seedlings are ready to break through the ground. If onion growers will keep this well in mind, they will soon realize that advantage can be taken of this fact to control the disease, and in the manner indicated on page 157.

Vitality of Smut Spores. Thaxter, in his investigation already referred to, has shown that the spores of *Urocystis cepulae* retain their longevity a long time. This is due, no doubt, to their peculiar structure. He found an abundance of smutted onion plants in a field which was definitely known to have rested twelve years from onions. This, then, would indicate that short rotations of four or five years are entirely inadequate to starve out the onion smut from any field. Even a twelve-year rotation would not accomplish the purpose.

Methods of Control

Formaldehyde Drip Method. Of all the onion diseases, smut is perhaps the easiest to control. In fact, with our present-day knowledge of this disease, one is hardly justified in having to put up with this trouble.

Since, as already stated on page 147, the spores of the smut fungus live in the soil from year to year, infection naturally takes place in the soil after the seed germinate and the seedlings are ready to break through the ground. It is comparatively easy at this stage to prevent infection. This is done by disinfecting the soil particles which are nearest to the seed and seedlings in the ground. The method is accomplished with the formaldehyde drip (Fig. 8, E). In this case, enough formaldehyde is added to the soil immediately around the onion seedlings to kill all smut spores in that vicinity. Once this is accomplished and the young seedling outgrows the danger point, infection will not take place when the seedling has passed a certain age. This is very obvious since the young plant when starting from the seed is small and tender and cannot keep the fungus threads of *Urocystis cepulae* from entering and growing in the leaves. As soon as the onion plants have formed four or five leaves, they become more resistant against the attacks of the fungus than the young seedling just breaking through the ground. Since the formaldehyde evaporates soon after it is applied, the best results are obtained when the chemical is applied at the same time that the onion seeds are sown. If the seed happen to be poor and the field has to be replanted, a second application of the formaldehyde must be given.

The apparatus used in applying the formaldehyde to the soil at seeding time is very simple. It consists of a galvanized iron tank with a pipe leading down to the furrow. Any tinner in any town will be able to make it. Similar apparatus is also offered for sale by certain manufacturers and by seedsmen. The size of the tank usually varies with the type of seeder which is used. For an average ordinary single-row seeder, a two-gallon tank will answer the purpose. This tank is placed behind the seed-box where the extra weight will generally rest mainly on the packing wheel. The pipe of the tank is so arranged as to drip the solution directly into the center of the furrow just before the packing wheel closes it. However, this same drip pipe should be far enough down to prevent spattering of the liquid on the shoe or the packing wheel. A cut-off valve in the pipe controls the amount of solution from the tank so that the operator can shut off the flow quickly wherever desirable, or especially at the end of each row. It requires about 200 gallons of the formaldehyde solution per acre. Hence, there should be about a $^{5}/_{16}$-inch flow of liquid from the tank. Occasionally the attachment may be modified successfully for use in the eight-row gang-seeder. If the soil tends to clog between the plow and the packing wheel, one or both of the seed coverers may be removed. In this operation, a thorough preparation of the seed-bed will make it considerably easier to apply.

It should be borne in mind that too strong a solution of formaldehyde will prevent the seed from germinating. On the other hand, too weak a solution will not control this fungus. On a practical scale, it is far more advisable to increase the strength and decrease the quantity of the liquid. This will, no doubt, reduce the expense of application. This, however, can only be done within a certain limit. The following is the method of preparing the formaldehyde for use in this method: To each gallon of water one ounce of 40 per cent formaldehyde is added (one pint to sixteen gallons of water gives the same dilution as one ounce to one gallon of water). This solution is then applied at the rate of 200 gallons per acre, or one gallon to about 185 feet of row. It is, of course, understood that the drip applies the formaldehyde only in the furrow where seed are sown. Where several rows of seed are sown close together for the purpose of producing onion sets, the quantity of solution is naturally increased in the same proportion.

In disinfecting the soil with formaldehyde on a large scale, one should purchase the chemical at wholesale prices, which vary considerably.

It is very essential that the grower should follow directions and never make the formaldehyde solution stronger than one ounce to a gallon of water or one pint to sixteen gallons of water. Solutions stronger than that will undoubtedly injure the germination of the seed. Experiments by Pammel have shown that, ordinarily, onion seed will germinate about 63 per cent in water. In a ¼ per cent solution of formaldehyde, 66 per cent germination is secured. In a ½ per cent solution of formaldehyde, 62 per cent germination results. In a 2 per cent solution of formaldehyde, 50 per cent germination is the result. In a 5 per cent solution of formaldehyde, 29 per cent germination is obtained, and in an 8 per cent solution of formaldehyde the germination is reduced to about 1 per cent. From this it is seen that the presence of a very slight amount of formaldehyde, up to ½ per cent, there seems to be a slight stimulation of germination, while stronger solutions were undoubtedly detrimental. The formaldehyde drip method is now being used in practically every state where onion smut is prevalent, and with good results.

Table 14 shows the results of using formaldehyde for controlling onion smut.

Heavy Seeding. The chief difficulty in infected soil is to obtain a good stand. To overcome this, growers are often in the habit of sowing three and four times as much seed as they ordinarily require. Such a practice cannot be recommended for the simple reason that the more seed we sow, the more plants will become infected and die. Furthermore, as the disease becomes well established in the land, no amount of heavy seeding will be of any value, as in this case it will be practically impossible to obtain any kind of a stand.

Crop Rotation. Mention has already been made on page 147 that the spores of the onion smut fungus are very long-lived. Thaxter has shown that these spores may remain at least twelve years or longer in the soil without losing their germinating power. This then would indicate that longer rotations will be necessary to starve out the fungus altogether. However, while crop rotation can not entirely eliminate the smut fungus from the soil, it is, nevertheless, capable of reducing it to a certain extent. Crop rotation is practiced in the Orange County onion district of New York. Corn and potatoes are the crops most commonly used in their rotation system. Frequently the lands are sown down to grass for three or four years with beneficial results.

Burying the Surface Soil. Various methods of burying the surface soil have been tried in New York State. One such method is deep plowing, in which the purpose is to bury the surface soil deep and at the same time bury the smut spores and prevent them from germinating. Such a practice may give good results the first year, but after that, smut will become as bad as ever. In some few cases upland soil has been added to infected fields. With this method the added layer

TABLE 14

Results of Experiments and Demonstrations in the Control of Onion Smut by the Formaldehyde Drip Method

State	Reporter	Treatment		Results				
		Strength of Solution (gallons water used with 1 pint formaldehyde)	Amount per Acre (gallons)	Per Cent Infected Plants		Yield (bushels per acre)		
				Treated	Untreated	Treated	Untreated	Increase
N. Y., 1917	Jagger, I. C.	21.875	250	11.1	88	487	28	459
		21.875	200	15.9	88	461	28	433
		21.875	150	18.3	88	395	28	367
		21.875	100	30.3	88	308	28	280
		18.75	250	5.3	88	500	28	472
		18.75	200	8.3	88	508	28	480
		18.75	150	7.2	88	487	28	459
		18.75	100	17.6	88	397	28	369

N. Y., 1917	Jagger, I. C.	15.62	250	1.0	88	491	28	463
		15.62	200	4.1	88	495	28	467
		15.62	150	4.4	88	491	28	463
		15.62	100	10.8	88	454	28	426
		12.5	250	3.2	88	464	28	436
		12.5	200	0.8	88	473	28	445
		12.5	150	1.7	88	440	28	412
		12.5	100	7.6	88	417	28	389
		9.375	250	2.6	88	439	28	411
		9.375	200	4.4	88	455	28	427
		9.375	150	0.9	88	446	28	418
		9.375	100	4.1	88	444	28	416
		Check plats (10)	....	(aver.)	88	(aver.)	28	
N. Y., 1918	Olive & Dye	16	225	1–7	28–38	816	514	302
		10	200	1	28–38			

TABLE 14—*Continued*

State	*Reporter*	*Treatment*	*Results*					
		Strength of Solution (gallons water used with 1 pint formaldehyde)	*Amount per Acre (gallons)*	*Per Cent Infected Plants*		*Yield (bushels per acre)*		
				Treated	*Untreated*	*Treated*	*Untreated*	*Increase*
N. Y., 1918	Dye, H. W.	16	200	10	49	826	447	379
		16	200	2	37	846	495	351
		16	200 approx.	...	...	555	261	294
		16	200 approx.	...	...	423	165	258
Penn., 1917	Orton, C. R.	16	...	10–15	90.0	553	374	179
Penn., 1918		4	...	10–15	90.0	586	287	299
Wisc., 1913	Walker, J. C.	32	118	27.5	24.0	341	320	12
		16	118	5.6	24.0	506	320	186
		8	118	2.6	24.0	588	320	268

Wisc., 1914		16	118	13.4	51.2	344	86	258
		8	118	10.3	51.2	283	86	197
		4	118	11.5	51.2	216	86	130
		16	236	10.2	51.2	396	86	310
		8	236	6.2	51.2	409	86	323
		4	236	6.3	51.2	299	86	213
Wisc., 1915		16	118	28.6	52.6	632	400	232
		8	118	15.4	52.6	722	400	322
		16	236	3.6	52.6	748	400	348
		8	236	3.2	52.6	655	400	255
Wisc., 1916		22	100	43.1	54.9	117	72	45
		15	100	29.0	54.9	164	72	92
		9	100	13.7	54.9	178	72	106
		22	150	31.4	54.9	182	72	110

TABLE 14—*Continued*

State	**Reporter**	*Treatment*	*Results*					
		Strength of Solution (gallons water used with 1 pint formaldehyde)	*Amount per Acre (gallons)*	*Per Cent Infected Plants*		*Yield (bushels per acre)*		
				Treated	*Untreated*	*Treated*	*Untreated*	*Increase*
Wisc., 1916	Walker, J. C.	15	150	24.2	54.9	207	72	135
		9	150	14.6	54.9	205	72	133
		22	200	17.7	54.9	296	72	224
		15	200	5.8	54.9	351	72	279
		9	200	7.1	54.9	247	72	175
Wisc., 1918	Walker, J. C.	16	200	2.5	25–75	682	186	496
Ohio, 1918	Selby, A. D.	25	200	Good results		Good results		

of soil must be sufficiently thick to prevent the smutty soil beneath from being brought up to the surface with the plow. The expense of this operation is so prohibitive that it seems hardly wise to try it.

Transplanting. Through the brilliant researches of Thaxter, it was found that onion-smut infection occurs only when the onion plants are very small and tender. Furthermore, he observed that transplanted seedlings were always free from smut. Sturgis, later, found that if the seeds were sown in a seed-bed soil free from smut and later transplanted in the infected fields, the transplanted sets would remain free from smut. In other words, he showed that onion seeds when previously reared in smut-free soil and then transplanted into smutty soil, do not contract the disease. Here, then, in reality lies the practical solution of the smut problem. The beneficial results of transplanting in the control of smuts are shown in Table 15.

Use of Lime. Promising results have been obtained in Iowa by the use of ground quick-lime at the rate of 75 to 125 bushels per acre. The lime is applied on the newly-prepared soil just before seeding. This treatment, of course, is by no means as effective as the formaldehyde treatment; hence, under all circumstances, the grower should not lose much time in trying out methods which give only partial relief. The formaldehyde drip method, and that of growing the plants in a healthy soil and then transplanting them to the infected land are about the only two reliable methods. The use of lime in some soils may, of course, stimulate the yields, but this is accomplished only through its indirect action as a fertilizer and not as a germicide in killing the smut spores.

TABLE 15

Effect of Transplanting on Smut Control

PLAT NO. 1

	Weight	*Quantity*	*Average Circumference*	*Per Cent Smutted*	*Per Cent Scallions and Missing*	*Remarks*
20 Rows Transplanted	387 lbs.	6 bu. 1 pk.	8.24 in.	0	2	
20 Rows Seed	212 lbs.	3 bu. 2⅕ pks.	4.98 in.	10	15	The actual percentage of smutted onions on these rows was much larger than appears, since many of the plants were completely destroyed
			PLAT NO. 2			
14 Rows Transplanted	81 lbs. 8 oz.	7½ pks.	6.8 in.	....	5	The soil on this plat was poor and ill-adapted to onions; all the bulbs were consequently small
7 Rows Seed Thinned	4 lbs. 15 oz.	½ pk.	3.4 in.	....	40	Most of the loss on the 14 seeded rows was caused by cut-worms The transplanted rows were practically untouched by worms
7 Rows Seed Not Thinned	11 lbs. 2 oz.	1 pk.	2.8 in.	....	40	

SUMMARY OF MORE RECENT INVESTIGATIONS

Recently, Anderson of the Massachusetts Agricultural Experiment Station has carried on some work on the onion smut fungus. His more important conclusions are as follows:

Spore Germination.

1. Spores as soon as mature germinate in the laboratory in onion decoction, sugar solutions, onion decoction agar, soil agar, manure decoction agar and various agars containing sugar.
2. They do not germinate in tap water, distilled water or soil water.
3. The presence of the onion or any substance from the onion is not necessary.
4. Freezing does not increase or hasten germination, but when spores are frozen in the ground they are not killed.
5. Free access to air increases the percentage of germination.
6. A period of rest in damp soil increases the percentage of germination, but is not necessary.
7. In the soil the spores do not all germinate at once, but become progressively prepared for germination. They do not wait until a host plant starts to grow near them.
8. Germination begins in three to six days after the spores are brought under favorable conditions.
9. A short hemispherical promycelium is first developed, and from this a whorl of branches grows out.
10. The branches grow as mycelium indefinitely

without producing conidia (sporidia). The older cells become devoid of their protoplasm progressively.

11. The germination process is very similar to the same process in other species of Urocystis, being almost identical with that of *Urocystis anemones.* Of the investigated species of this genus, only *U. violae* produces sporidia.

As a Soil Saprophyte. Urocystis cepulae lives and grows as a saprophyte indefinitely in the soil, its growth being favored by manure.

The Fungus in Pure Culture.

1. It may be grown in pure culture on a wide range of culture media, and shows cultural peculiarities by which it may be distinguished from other fungi.

2. Sugar in the media greatly increases the growth. The same substance probably accounts for its rapid growth in the host.

3. Starch furnishes a very poor source of carbon.

4. Decoctions from soil or manure furnish all the essentials for growth.

5. A small amount of acid checks its growth.

6. Freezing does not kill the mycelium.

7. No sporidia (conidia) have been found by the writer in pure cultures or in soil.

8. The mycelium at an early stage breaks up into short plump cells which have all the functions of sporidia and are probably of great importance in dissemination.

Mode of Infection.

1. The organism gets into the soil either by means of spores when the sorus is broken up, or as mycelium which grows from the lesions when in contact with moist soil.

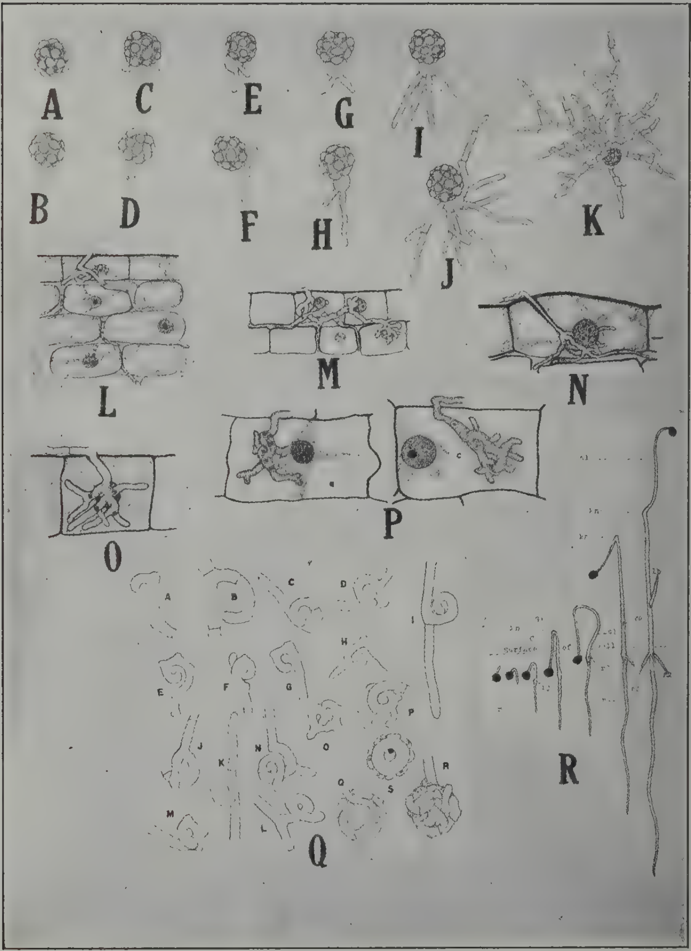

FIG. 9.

A to *K*. Stages in the germination of the spores of onion smut. *L* to *N*. Infection from outside of cotyledon. *O*. Infection from cotyledonary cavity. *P*. Haustoria in host cells. *Q*. Stages in the formation of a spore ball. *R*. Stages in the germination of an onion seed. (*A* to *R* after P. J. Anderson.)

2. Infection occurs during the time from the second day after the seed germinates until about the time that the first leaf appears on the side of the cotyledon, after which the plant is immune.

3. Infection occurs only through the cotyledon, and any part of its epidermis may serve as the point of infection.

4. The infecting hypha bores directly through the outer wall of the epidermal cell, forms a hyphal gnarl inside the cell, and then passes through the inner wall into the intercellular spaces where it grows during the rest of its development.

5. Many infections may occur on the same cotyledon.

6. The incubation period is less than one week.

7. Large complicated haustoria are formed within the host cells.

8. An infected plant recovers if the fungus fails to reach the growing zone; but if it once becomes established in this zone, the plant never recovers, and most if not all the leaves will contain lesions.

9. At the close of the incubation period the mycelium is in dense masses between the cells, and from this the spores develop in sori.

Method of Spore Formation.

1. The spore begins as a recurved lateral or terminal branch, forming a crozier, circle or short spiral.

2. Branches arising from the circle (crozier) form a close covering about the terminal (fertile) cell.

3. By adhesion of the cells of the covering hyphæ and rapid expansion of the fertile cell, the enclosing hyphæ are separated into the scattered elements which appear as the sterile cells of the mature spore.

4. The fertile cell contains a single, large nucleus,

and each sterile cell a single small nucleus. Probably the large nucleus is a result of fusion. (See also Fig. 9, A to R.)

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CHAPTER XVI

RUST

Caused by *Puccinia porri* (Sow.) Wint.

ONION rust is generally of little economic importance in the United States. However, it has been found several times in Connecticut, and in Nebraska on *Allium cepae bulbellifera.* Clinton in Connecticut found both the uredospore stage and the teleuto spore stage on Egyptian onions, thus establishing the identity of the fungus. Little is known about this disease and about methods of control. Ordinarily it does not attack market varieties. It is more commonly found on the familiar Egyptian variety and on the chives.

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WATERY SOFT ROT

Caused by *Sclerotinia libertiana* Fckl.

The fungus which causes watery soft rot on onions also causes serious diseases on lettuce, cabbage, and other crops in the field. On the onion, however, it has been observed as a storage and transit trouble. As the name indicates, affected bulbs are watery and soft rotted. This disease is found on onions originating in California, Illinois, and Texas, showing a loss ranging from 5 to 40 per cent. Little is as yet known about the factors which favor this disease in storage and in transit. It is likely that the bulbs were originally infected in the field. Since the disease makes its appearance only under poor conditions of ventilation, a remedy seems in sight. Attention should be given to the proper construction of the storage house and to thorough curing in the field before storing.

BLACK MOLD

Caused by *Aspergillus niger* Van Tiegh.

Black mold is a disease which is often mistaken for smut. However, it may be readily distinguished from the latter by the fact that this trouble usually attacks the mature onion, especially after harvesting, or during storage and in transit. In Ohio black mold is frequently met with in the field, but there, too, it is primarily a trouble of mature onions, the disease ordinarily becoming serious in storage or in transit. The black mold disease was first found in Ohio in 1916. In the same year, it was also found in Virginia and on onions from Illinois and Kentucky which were stored in Ohio in 1916. The disease is very prevalent in California where it occasions considerable damage. The same is true of Illinois, Indiana, Louisiana, Missouri, New York, and in Texas. In the latter state black mold is very common when onions are dug during a prolonged wet spell, and it becomes difficult to dry the bulbs properly before shipping. The disease then appears in great virulence in transit, where it causes considerable damage, especially opening the way to secondary infection by soft rot (*Bacillus carotovorus*).

Symptoms. Infected onions show various blackened areas on the outer bulb scales (Fig. 10, A). The infected areas are first light brownish to yellowish, finally turning dark to brown in color. The dark areas consist merely of the fruiting heads of the causal fungus. As the numerous infected areas enlarge and meet, the infected bulb scales become blackened and slightly softened. Ordinarily, infection starts about the upper part of the onion, indicating that the disease gained an entrance through the torn tops, and then gradually worked downwards between the layers of the onion scales. Infection may also take place through cuts and bruises made when the onions are harvested, or when roughly handled during loading in transit, or in storage in commission houses. The large white or Spanish type of onion when seriously infected with black mold becomes objectionable to the market. The general effect of the disease is to cause the outer layers of the bulb to shrivel, wrinkle, and dry up (Fig. 10, B). Frequently soft rot (*B. carotovorus*) follows the work of black mold, so that infected bulbs become mushy, soft, and in a short time a mass of putrid, decayed material. Likewise, the diseased outer bulb scales may be removed and when such onions are exposed to air and sunlight, the black mold disease will subside. In Ohio, Van Pelt found that the spores of *Aspergillus niger* are carried on the onion seed so that at least fifty per cent of reduction in germination is directly traced to the effect of the fungus.

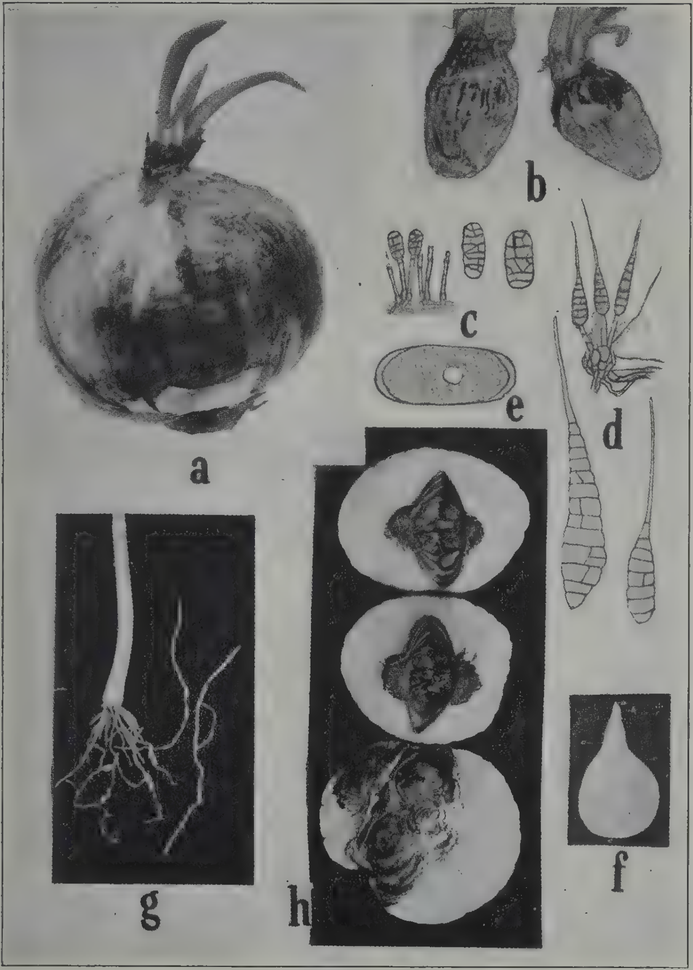

FIG. 10.

a Black mold of white onion, *Aspergillus niger*. (*a* and *b*, courtesy of Professor A. D. Selby.) *b*. Two white onions in an advanced stage of decay from black mold, *A. niger*. *c*. Conidiophores and conidia of *Macrosporium sarcinula*, var. *parasiticum*. *d*. Conidiophores and spores of *Macrosporium porri* (*c* and *d* after R. Thaxter). *e*. Egg of *Heterodera radicicola*. *f*. Female worm of *H. radicicola* (*e* and *f* after N. A. Cobb). *g*. Onion root knot. *h*. Splitting of mature onions in field due to sudden growth after dry spell.

Control. Since black mold spores are carried on the seed, Van Pelt recommended the use of the formaldehyde drip, such as is carried out for the control of onion smut. This recommendation is, no doubt, advisable in those states where *Aspergillus niger* attacks the young onion seedlings and sometimes causes trouble in the field. Under Texas conditions, however, *Aspergillus niger* seldom, if ever, causes any trouble in the seed-bed or in the field, so that the formaldehyde drip method would not be justified. To control the spread of black mold on mature onions, they should be dug as far as possible during dry weather and allowed to dry thoroughly before they are put away in crates and shipped or placed in storage. In fact, onions which have been properly matured and cured will seldom, if ever, be troubled by black mold. The disease, however, nearly always follows conditions of improper drying of the bulbs, or improper ventilation in storage or in transit. Furthermore, as far as possible, every care should be exercised to prevent unnecessary bruising of the outer bulb scales.

In those states where black mold attacks the green sets, Van Pelt recommends, as he does to the onion growers in Ohio, that the infected sets be soaked for six hours in a formaldehyde solution consisting of one pint of the chemical in 25 to 33 gallons of water. Other results equally effective were obtained by soaking affected sets for six hours in a solution of calcium hypochloride, or ordinary bleaching powder solution, at the rate of one-half pound of this chemical to one gallon of water.

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CHAPTER XVII

NECK ROT

Caused by *Botrytis allii* Munn

Economic Importance. Neck rot seems to be a storage disease primarily. The trouble is most prevalent in storage houses in New York and Michigan. Frequently, the margin of profit from stored onions will be wiped out by neck rot. This disease has practically wiped out the white onion in many onion sections in New York and Michigan. It seems that the disease is more virulent on the tender thin-skinned varieties. Similarly, heavy losses are often entailed by neck rot in the retail grocery stores, especially those dealing in southern onions. The Texas white onion on the New York market is often subject to about 2 per cent rot. Likewise, the disease is often met with on bulbs of the Spanish and Bermuda onions on the market. Ordinarily, the loss from neck rot in storage ranges from 7 or 8 per cent to frequently 50 per cent of the crop. The losses usually fluctuate with the growing seasons, which are termed "poor seasons or good seasons for onions."

Name of the Disease. Neck rot has been known under a variety of names such as mold, gray mold, onion rot, storage rot, rot, dry rot, onion bulb rot, dry neck rot, stem rot, black neck rot, and neck rot. The term neck rot best describes the symptoms of the disease. Neck rot seems to be confined to the onion only, *Allium cepa,* a species which contains many varieties.

Distribution. This disease seems to have been described as early as 1876 by Sorauer in Germany. In 1907 Bruck stated that this disease seemed to be common in Europe. In 1903 Voglino reported it from Italy and France. Massee reported it in England in 1894. In 1890 Halsted first noticed it in the United States. In 1903 Clinton found it quite prevalent in Connecticut, and in 1910 it was reported by Selby in Ohio. In 1914 Jackson found it quite troublesome in Oregon. Likewise, as reported by the *Plant Disease Survey* (Fig. 11, A), neck rot seems to be prevalent in Illinois, Ohio, Pennsylvania, Oregon, Wisconsin, Michigan, New York, Maryland, Connecticut, Massachusetts, and Washington. Traces of it are also reported from Florida, California, Kentucky, Missouri, Texas, Idaho, and New Jersey.

Symptoms. The symptoms of neck rot vary with the area at which infection takes place. On the leaves, it begins as a small white spot which later enlarges. The spots are frequently surrounded by a yellowish area, the tissue of which is water-soaked in appearance. This at once distinguishes it from the white ring disease, a physiological trouble of onion foliage (see p. 116). Frequently infection occurs where the leaves are folded over or where they have been injured by thrips. In every case of infection, the diseased tissue becomes water-soaked and presents a boiled appearance; the green of the leaves disappears and is replaced by a yellowish brown.

On the neck, the disease occurs as tufts of spore-bearing stalks, the tips of which are covered by smoky

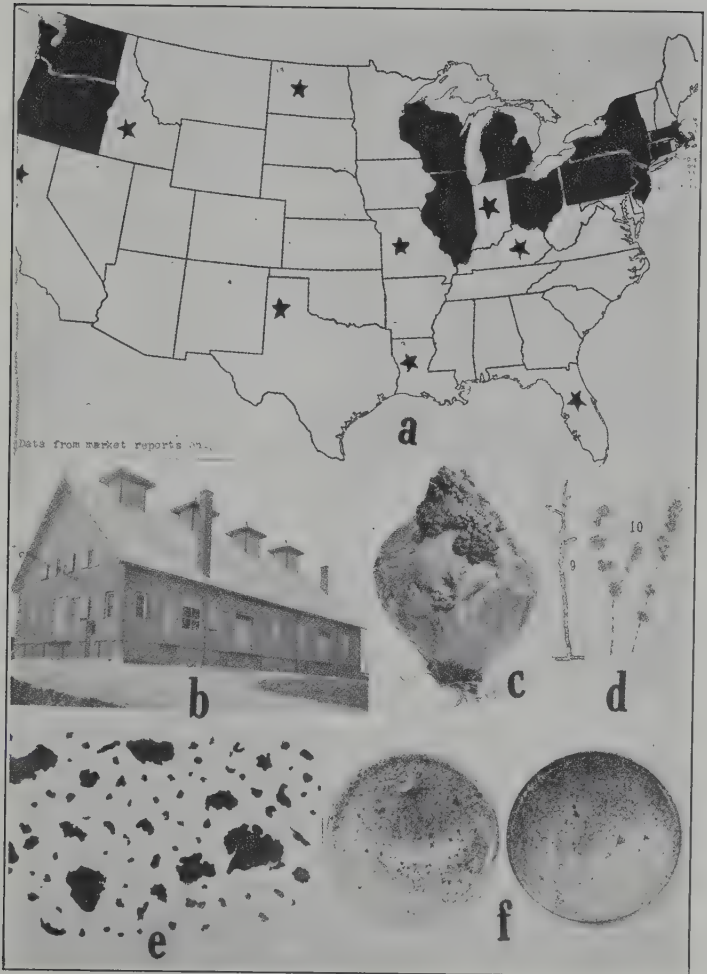

FIG. 11.

a. Occurrence of neck rot in the United States (*a*, courtesy of *U. S. Plant Disease Survey*). *b.* Model storage house for onions. *c.* Neck rot stage, showing mass of sclerotia on neck of affected bulb. *d.* Sporophores and spores of *Botrytis allii*. *e.* Sclerotia of *B. allii*. *f.* Two plate cultures of *B. allii*. (*b* to *f* after M. T. Munn.)

gray spores. Likewise the fungus is found fruiting on the necks of the "scallions," "bullnecks," or "thick-necks" which are put away in storage. On such bulbs the fungus becomes very apparent, because such onions are neither dry nor mature. From the neck and outer leaves the causal fungus works down into the bulbs and in the long run destroys it.

On the bulbs, and in storage, the typical neck rot is readily noticeable by the appearance of roundish black fungus bodies (sclerotia) (Fig. 11, C). These sclerotia are either found sparsely or in crusts which surround the entire neck of the bulb. Such crusts may be readily peeled off, in which case it is found that the outer two or three bulb scales have become infected and are thickened. Sclerotia are also found on the bottom of the bulb plate or between the scales. Diseased bulbs are soft, giving off considerable liquid, and are offensive in odor. Here, however, the putrefaction is no doubt due to the invasion of bacteria and other organisms. Where no secondary infection takes place, diseased bulbs become dry; hence the term dry rot or dry neck rot.

Where infection takes place on bulbs stored in the drier part of the house, the bulbs will be found to be covered by smoky gray-colored fungus spores in the region of the neck. When such a bulb is cut open, it will be found that the bulb scales are filled with mycelium of a dirty white to dark brown. Likewise, the bulbs are softened and discolored.

Occasionally the causal fungus is known to attack the roots of the bulb in the field; in which case, the roots will entirely rot off. The numerous sclerotia are formed at the bottom of the plate of the bulb.

The causal fungus has often been found fruiting on dead leaves, stems, and on the base of seed stalks in a number of onion seed fields in New York, giving the seed heads the appearance of being blasted. Careful examination will show that the infected seed heads are covered with coarse branching mycelium of the causal organism and the floral parts have been killed.

Method of Infection. Neck rot infection may take place either through the germination of the spores of *Botrytis allii* or through the sclerotia. However, as long as the spores find no suitable moisture either on the bulbs or on the leaves, infection will not take place. When dry spores lodge at the base of the leaf, they usually find sufficient moisture in the field from dew to germinate and to penetrate its host. Under storage conditions, poor ventilation and lack of means to carry out the moisture from sweating will favor the germination of the Botrytis spores, and hence permit them to penetrate the bulbs and cause infection. Frequently also the spores of Botrytis may fall on the blossom heads in the field, and cause a germination on the stigmas, which are always more or less moist. They then may penetrate the stigma, anthers, and petioles of the flowers and cause a blasting of the flower-heads. Finally, infection may also occur when the sclerotia come in contact with cracks or bruises on the foliage or on the bulb proper.

There seems no doubt that a large percentage of infected bulbs in storage were originally infected in the field. The majority of infections take place at the neck while only a small percentage occur from the sides and the bottom of the bulbs. Occasionally, as already stated, a small percentage of infection may also take place through the roots, then working into the bulb plate. Frequently, when wet weather occurs during harvesting and growing period, and while the bulbs are drying in the field, a large amount of infection will take place when the bulbs are placed in the windrows. Rotting then will not start very appreciably until these bulbs are placed in storage. Frequently, infection in the field will take place through injury of bulbs, as they are bruised by the topping machine. In fact, many of the onion stores in New York State look with disfavor on machine-topped onions. Those machines, if not properly handled, will bruise the sides of the large bulbs. It is fortunate that rotting in storage will not spread materially. A healthy onion bulb may lie side by side with a diseased one and will not contract the disease if its outer scales have well dried and cured.

The Fungus. There seems to be considerable confusion as to the name of the neck rot fungus. Sorauer described an onion disease due to *Botrytis cana* (Pers.) Fr. as supposedly the sclerotial stage of *Sclerotium cepae*. Later, he referred to *Botrytis cana* as the sclerotial stage of *Sclerotium cepivorum*. Halsted thought that the onion bulb rot of the United States was due to *Botrytis parasiticum Cav.* Massee referred to onion Botrytis and *Sclerotinia bulborum* Walker as being one and the same organism. Clinton suggests that the onion rot in Connecticut is possibly due to *Sclerotinia bulborum*, and Selby in Ohio thought that the neck rot there was due to *Sclerotinia cepivorum* Berk. It seems certain from the work of Munn at the Geneva Experiment Station that the onion neck rot fungus was not properly named and therefore renamed it *Botrytis allii* Munn., a brief description of which is as follows: Colonies in pure culture dirty white, becoming smoked gray, then felt-like (Fig. 11, F), mycelium coarse, with no definite method of branching, conidiophores short, erect, numerous, septate, occurring either singly or in clusters not often branched on the host plant (Fig. 11, D); conidia, hyaline or very dilutely colored, elliptical and often slightly tapering at both ends, attached by a short sterigma to the vesicles in small clusters. Sclerotia (Fig. 11, E) are dull black, firm, white inside, black outside, highly wrinkled; sclerotia germinate by means of hyphæ which immediately produce conidiophores; no apothecia are formed.

The relationship of temperatures to this fungus is interesting. *Botrytis allii* will survive a temperature of 122° F., and both spores and mycelium will stand considerable freezing. It is, therefore, comparatively easy for the causal organism to live over in the field from year to year.

There seems no doubt but that the fungus, *Botrytis allii,* kills its host by means of an enzyme which is toxic to the cell tissue. This enzyme is secreted by the growing mycelium; hence it is common to find in a diseased area of any affected bulbs a ring of dead discolored cells apparently free from fungous mycelium which separates the healthy from the dead tissue. The cells are first discolored and later collapse, after which they become invaded by the causal fungus. Within the host, *B. allii* also produces an appreciable amount of oxalic acid, which, no doubt, also helps in killing the invaded cells.

Methods of Control. Although neck rot is a storage disease, there are many factors which favor infection. The condition of the bulbs during harvesting is an important factor in neck rot infection. Onion bulbs with large green tops or "bullnecks" are especially susceptible. It is advisable to allow the tops to ripen and shrivel, and the outer skin of the bulb to dry considerably before the crop is harvested. Furthermore, bulb rot infection is proportionate to the amount of downy mildew or other diseases which may attack the foliage in the field previous to harvesting. In this case, the neck rot merely follows the weakened bulbs. It seems that the kind of fertilizer used in the field has no effect on neck rot infection. There are, however, cases where heavy infection with neck rot is encountered, where fertilizers were applied in incorrect proportion, or where too much manure was used, thus resulting in tender growth.

In reality, the amount of neck rot depends on the degree of maturity of the bulbs, the extent of curing, and weather conditions during harvesting and curing. The storage conditions under which the onions are placed are also important factors. It has been found that onions grown on uplands will dry and cure better and as a result will be freer from neck rot. The factors which are favorable for neck rot infection in storage are over-heating and poor ventilation. While the structure of the house has something to do with proper curing, the best of houses, of course, will not carry through a crop when the bulbs are brought in wet, when they are poorly cured, or when the weather is unfavorable and raining most of the time. Storage houses with flat roofs and poor methods of ventilation are ill-suited for onions. Proper ventilation is one of the most important factors in the control of neck rot in storage. The best storage house (Fig. 11, B) is that which is provided with a roof of a steep pitch and preferably double so as to draw out the moist air. The ventilation vents should be kept closed during damp moist days, but kept wide open during dry favorable weather. A high temperature and a relative humidity of 65 to 70 per cent is undoubtedly detrimental to good keeping and favorable to a large per cent of neck rot infection.

Since it is plain that storage conditions are very important in controlling neck rot, it is possible to put the bulbs through a rapid drying out of the necks. This may be accomplished by the use of artificial heat applied immediately after harvest. This may be done by placing the onions under the influence of a passing current of air heated to 100° or 120° F. In this case, the onions are placed in shallow flats and put under the influence of the heated air until the necks are thoroughly dried. On a commercial scale, it is, of course, necessary to have a special device for heating or a special system for applying the heat in rooms before the onions are finally placed in storage. While this method is still in its experimental stage, it no doubt offers great promise in the control of neck rot.

Spraying the onion crop with 5-5-50 Bordeaux, to which is added resin to make it stick better, is advisable in so far as it helps to control downy mildew and other diseases and hence incidentally also helps to control neck rot. Fumigation of the house while the onions are stored is of no benefit at first, because the average storage house is not tight enough to retain the fumes of either formaldehyde or sulphur and because the gas from the fumigation cannot penetrate the mycelium, which works to the bulb. The safest and only method of control is careful handling in the field and housing the crop in well-ventilated storage houses.

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LEAF MOLD

Caused by *Macrosporium sarcinula* var. *parasiticum* Thuem.
Macrosporium porri Ell.
Macrosporium solani Berk.

The first two Macrosporiums were described by Thaxter in Connecticut as causing a serious foliage disease on onions. This is especially true of *Macrosporium porri,* the latter of which produces pale spots, while in *Macrosporium sarcinula* the spots are more circumscribed and less inclined to cause injury through rotting and breaking off of the seed stalk at the point of infection. In short, according to Thaxter, *Macrosporium sarcinula* seems more often to follow injury caused by downy mildew, *Peronospora schleideniana,* while *Macrosporium porri* seems to be a true parasite under Connecticut conditions. In Louisiana *Macrosporium sarcinula* was responsible for the destruction of forty or fifty per cent of the seed onion crop in the LaFourche onion district in 1917. In this case the stems of the seedlings become covered with the black mold, thus rotting and falling over.

Recently Walker described a bulb rot which is common to the white varieties of onions attacking as it does, large bulbs and bottom sets in Wisconsin and Illinois. Infection ordinarily takes place at the necks of the top bulbs after harvesting. A semi-watery decay results, in which the affected tissue becomes deep yellow and wine red in color due to pigments produced by the causal fungus. Finally, the decayed tissue becomes dark brown to black because of the development of the dark colored mycelium and spores. The rot is usually confined to the outer three or four bulb scales. Where infection occurs at the bottom sets, the result is a total loss. The causal fungus, *Macrosporium solani,* is said to sporulate very sparsely in culture. No methods of control are as yet known. (See Fig. 10, C and D.)

As to controlling the leaf mold caused by *Macrosporium sarcinula,* and *M. porri,* it is recommended that the crop in the field be sprayed with Bordeaux mixture to prevent infection of downy mildew, *Peronospora schleideniana,* and especially to protect the tops from attacks of thrips (methods of treatment are given on p. 228).

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CHAPTER XVIII

PINK ROOT

Caused by *Fusarium malli Taub.*

THIS disease has received attention by the authors primarily as it attacks onions in Texas. In fact, this new malady has, during the last few years, made onion-growing unprofitable in some localities of the Empire State. The early history of the disease is not known; Mr. Gilbert, of the United States Department of Agriculture, at one time did preliminary work but it was never published. Neither is there any mention in literature of a disease which would correspond to the pink root trouble. It is very likely that the disease has existed a long time in some of the tropical countries, but, owing to the lack of investigations on tropical plant diseases, pink root has attracted no attention. This disease is now prevalent in the Bermuda Islands, the original home of the Bermuda onion, so that it is very likely that pink root was originally introduced from there into the United States.

The present distribution of pink root is only partly known on account of the fact that the disease is beginning to attract more attention in those states where onions are considered an economic crop. The disease may also be prevalent in other states where this crop is grown on a small scale and for home use only. The present known distribution of pink root of onions is as follows: In Texas, it is found practically wherever onions are grown, especially in the following counties: Webb, Dimmit, Zavalla, La Salle, Cameron, Hidalgo, Nueces, and Frio. In Louisiana it has been reported by Walker in LaFourche parish and more recently by Edgerton. The disease there seems to be general on onions in some fields, but apparently does not cause any serious damage. Walker in 1919 further reported pink root from California in the Stockton region. Of 2,500 acres devoted to onions, twenty acres were so badly attacked by the disease that the crop was reduced by 50 per cent. The disease in California exhibited symptoms very similar to the pink root trouble as it occurs in Texas. The disease was also reported in California by Miss E. H. Smith, and by Milbraith in many of the Japanese onion districts near Stockton, and in the Delta and Coachella Valley. From Indiana the disease is reported by Gardner as occurring in one field in De Kalb County. It is also found in Lake County without doing any damage. In New York, Dye reports that pink root is present in twenty-five per cent of the fields in Wayne County, reducing the yields considerably. Whether the pink root in New York and Indiana, as well as in Louisiana, is the same as that which occurs in Texas and California remains to be determined. It is very probable that the disease is the same and if not, it is probably caused by a species of Fusaria, closely related to *Fusarium malli,* the cause of pink root in Texas. Diseased specimens of onions affected with pink root were collected by the junior author in Des Moines, Iowa, in August, 1917. Onion specimens affected with the typical pink root disease were forwarded to the authors by Outerbudge of Paget East, Bermuda.

Economic Importance. Estimates of losses from pink root were made by the authors in counties in Texas where this disease is quite serious. In general, the losses from pink root in badly diseased fields vary from thirty-five to fifty per cent, and there is an occasional total failure. Assuming a normal yield to be about 400 crates per acre on good land, the losses from pink root will vary according to the following conditions: (1) The yields will be reduced when slightly or badly infected sets are planted in a healthy soil, the disease in this case being introduced into the new land with the diseased sets. Specific instances in many cases have shown a distinct decrease in yield of twenty-five to seventy-five crates per acre, or a direct loss of six to eighteen per cent. Similar losses will occur when healthy sets are planted in a soil which was previously infected with the pink root disease. In this case the healthy sets become infected with the disease which is already present in the soil. (2) Heavy damage will occur when diseased sets are planted on infected pink root land; in which case, it is not uncommon to meet with losses varying from 100 to 200 crates per acre, or a direct crop reduction of 25 to 50 per cent. The losses are estimated in terms of bushels and not in dollars and cents, because prices fluctuate every year.

Pink root invariably opens the way to infection of black mold (*Aspergillus niger*) and soft rot (*Bacillus carotovorus*). This occurs especially when infected onions are dug during wet weather and shipped in transit under poor conditions of ventilation. The pink root disease does not attack the bulb itself, but only the crown plate and the growing roots, so that growth is decidedly interfered with. The disease, by killing the growing roots as fast as they are formed, prevents the bulbs from developing into normal size. Affected bulbs spend all the energy during the growing season in an attempt to outgrow the disease and to produce new roots, which, however, are being constantly killed.

Studies by the authors have shown that pink root is not only able to attack all varieties of onions, but also all varieties of garlic, all varieties of shallots, and all varieties of the multiplying onions or Egyptian onions. The disease is, however, unable to attack any other hosts which belong to the Liliaceous or onion family. The Narcissus, Tulip, Funkia, Iris, as well as the German Iris, the Freesia the Calla Lily and Lillium Trifolium were all found to be resistant. Of the American varieties of onions that are susceptible to pink root, the following may be mentioned: the Yellow Dutch, Strasburg, the Yellow Danvers, the Australian Brown, Large Red Globe, Large Red Wethersfield, Large White Globe, White Portugal (Philadelphia), and the White Silverskin, all seem to be decidedly susceptible to the pink root disease. These are, however, mostly northern-grown varieties, which are seldom, if ever, grown in the South, especially in the Bermuda onion districts of Texas. Of the varieties grown in Texas, the Denia, a Spanish type, is especially susceptible to pink root when transplanted in an infected pink root soil. This means that on badly infected land neither the Denia nor any other of the Spanish varieties should be planted. Fortunately, however, the true Bermuda or Crystal White Wax and the White (Yellow) Bermuda, which are extensively grown in Texas, are decidedly more resistant to pink root than any other group or class of onion tested. Practically all of the multiplier varieties of onions, as well as shallots, seem to be highly susceptible to the disease. Of the varieties of garlic, several strains of the Mexican and Italian seem to be more susceptible to pink root than the large-growing kinds known as the Chinese. This means that on a pink-root-infected land where garlic is extensively grown for commercial purposes, the Chinese variety should be given preference. Of the Mexican and Italian varieties the pink type of garlic seems to be more susceptible than the white. Furthermore, the Mexican or Italian whites are not so resistant as the large Chinese white types already mentioned. The pink root on the garlic, shallots, and the multiplier onions is similar to that of the onion. Therefore, whatever applies to the onion applies to these other hosts.

Symptoms. The symptoms of pink root of onions, as well as of the other hosts mentioned, are very striking. As already stated, the disease is confined to the growing roots and to the bulb plate or crown, but not to the onion or bulb itself. This at least holds true of the pink root as it has been studied in Texas. This is especially mentioned because of the fact that in some states species of Fusaria are known to cause a rot of the onion bulb itself, which, however, is different and should not be mistaken for the pink root disease.

Affected roots may first become yellow (this is not always the case), and then dry and pink, the color becoming more intensified as the root shrivels and dries up. The pink color, however, slightly fades as the roots are exposed to the sun. Ordinarily pink root appears in the seed-bed. In the field it may be met with in practically all stages, from the time the plant begins bulbing to the time in which the bulbs approach maturity. In light infections the disease attacks only a few roots, the latter of which will show the characteristic drying and pink root color. In advanced stages, however, every root of the bulb may be affected. In this case the roots become pink as fast as new ones are formed. Such plants at the end of the season have spent all their energy producing new roots, thus becoming permanently stunted and failing to produce a marketable-sized bulb (Fig. 12, B). On carefully examining such onions, one will find that as a result of the disease, a projecting nipple is formed at the bottom plate of the bulb (Fig. 12, A and J). The nipple in this case merely indicates the area in which the old roots were produced and died and the outer demarcation where new roots were continuously being formed.

In the seed-bed the disease, even when serious, may not attract attention and will seldom definitely stunt growth; hence outwardly there is really little or nothing to indicate the presence of pink root. However, when the green sets are pulled for transplanting in the field, the characteristic pink on the dead roots will not fail to attract attention. From what will be stated shortly, it will pay the grower to cull out and discard every onion which shows the least trace of pink root. At digging time, the diseased bulbs in an infected field when exposed to the sun for drying will show the pink-root color and thus contrast strongly with the white of the healthy roots.

Frequently, and largely on account of favorable weather or cultural conditions, the onion plant in a pink-root-infected soil seems to grow faster than the disease can destroy the roots. This results in a mature bulb which conforms to the average market size. It is, therefore, not uncommon to find growers who seem to make a fair crop on infected land and, because of this, claim that pink root is not a serious disease of economic importance.

Cause of the Disease. For a long time onion growers, in Texas particularly, have maintained that pink root was not a disease, but rather a condition brought about by the presence of alkali in the soil or through a weakening of the plant brought about by an attack of thrips. This, however, has not proved true, since the authors have definitely shown that pink root is caused by a definite fungus which is directly responsible for the disease. Careful soil analyses by Dr. G. S. Fraps of the Chemistry Division of the Texas Agricultural Experiment Station have shown that alkali may be developed in the onion districts but its association with pink root is only incidental. It is not uncommon for the soil to become alkali on account of an excess of nitrates. In this case care should be taken not to use nitrate of soda as a top dressing, but to use instead sulphate of ammonia. Where soils are affected with other forms of alkali, the land should be provided with ample drainage, and irrigation given in such quantities as to wash out the alkali. In soils such as Laredo silty loam and Laredo clay loam, both of which are prevalent in Webb County, Texas, manure or a rotation of crops which will add vegetable matter, or humus, will be greatly beneficial in neutralizing the effect of the alkali. Whatever may be said of the presence of alkali in the soil infected with pink root, it can be definitely stated that the alkali therefore does not bring about the pink root disease. Table 16, which shows the alkali, in parts, per million of soil, clearly indicates that there is not enough alkali present in these soils to account for the pink root disease. Furthermore, soil samples taken from spots where the chemical analyses were made, and

TABLE 16

Alkali in Parts per Million of Soil

Sample No.	*Kind of Soil*	*Kind of Alkali*			*Total Alkali*
		Nitrates	*Sulphates*	*Chlorides*	
11528	Webb fine sandy loam, surface soil, much pink root	1050	237	114	1401
11529	Subsoil 11528, 6 to 12 inches	750	258	125	1133
11530	Subsoil 11528, 12 to 24 inches	1050	95	166	1311
11531	Subsoil 11528, 24 to 36 inches	300	208	197	705
11532	Alkali scrapings	5650	1465	2501	9616
11533	Webb fine sand, near road, some pink root	120	286	284	690
11534	Subsoil 11533, 6 to 12 inches	90	204	148	442
11535	Subsoil 11533, 12 to 24 inches	0	201	99	300
11536	Webb fine sandy loam, no pink root	30	300	191	521
11537	Subsoil 11536, 6 to 12 inches	30	296	172	498
11538	Webb fine sand, good soil, no pink root	30	216	147	393
11539	Subsoil to 11538, 6 to 12 inches	8	200	218	226
11540	Laredo silty loam, much pink root	4200	0	472	4672

11541	Subsoil to 11540, 6 to 12 inches	1500	54	417	1971
11542	Alkali scrapings	450	570	345	1365
11543	Laredo clay loam, some pink root	3	438	429	860
11544	Subsoil to 11543, 6 to 12 inches	0	302	261	563
11545	Laredo silt loam, no pink root	15	320	244	579
11546	Subsoil to 11545, 6 to 12 inches	5	237	241	483
11547	Laredo silt loam, no pink root	3	176	203	382
11548	Subsoil 11547, 6 to 12 inches	0	138	219	357
11549	Webb fine sandy loam, no pink root	3	213	180	396
11550	Subsoil to 11549, 6 to 12 inches	0	160	201	361
11557	Laredo silt loam, much pink root	0	226	170	396
11558	Subsoil to 11557	0	233	117	350
11559	Webb fine sandy loam, much pink root	8	298	289	595
11560	Subsoil to 11559, 6 to 12 inches	10	217	256	483
11588	Soil near peeler	....	....	9950	9950
11589	Subsoil to 11588	....	....	3298	3298

disinfected with formaldehyde applied in sufficient quantity not to wash down the salts, showed that the pink root fungus present in that soil was seemingly killed. As a result, a clean crop of onions was produced. This, then, should settle any claim as to alkali being the cause of the disease.

From investigations by the authors, it was definitely shown that the causal organism of pink root (*Fusarium malli*) is spread about by various means, chief of which may be mentioned the soil and infected green sets.

The Soil. It is a well-known fact that the largest onions and the heaviest yields are generally produced on new land and on lands which are rich in humus and plant food, and which have not, as yet, become infected through a system of continuous onion farming. Similarly, the greatest damage from pink root is actually met with on land known to be deficient in plant food, especially nitrogen and humus. This is especially the case when onions were grown on the same land for a period of years. Once the land becomes infected, the disease establishes itself more permanently the longer the onions are grown on it. This condition has actually occurred in some onion sections in Texas, and many growers are confronted with the serious problem of dealing with badly infected land.

It is not uncommon for new fields to become infected through the tools which are used on diseased lands. In this case, the implements may actually carry particles of infected soil, which may adhere to the plow, the cultivator, the hoofs of the working animals, and even to the shoes and clothing of the workers. Anyone can satisfy himself by taking a soil which has never grown onions before and sterilize it under pressure of fifteen pounds of steam for three or four hours at two- or three-day intervals and then add to that soil a pinch of dirt taken from a field known to be infected with the pink-root disease. If healthy onions are planted on such a soil, the plants will contract the disease and exhibit the same symptoms as occur on diseased plants in normally infected fields.

The Sets. It is customary in the many onion districts in the United States and especially in Webb County, and in Texas in general, not to plant dry sets in the field for the main crop. It has been found by most growers in Texas and in other states that the use of dry sets invariably results in the production of too many "doubles" and "splits," which the market will accept only at greatly reduced prices. For this reason onion seed is planted in regular seed-beds, and the resulting green sets are transplanted in the field. When seed are planted on infected soil, the green sets will invariably contract the disease and then carry it to the field. This explains one of the more common ways in which the pink root disease has been spread and may be spread to new localities where soil and climatic conditions are favorable for the disease. It is extremely easy to introduce the pink root experimentally in a new soil by planting infected green sets in a soil which has been sterilized either with formaldehyde or steam. Not only do green sets introduce the disease into the new fields, but such sets are decidedly handicapped in the sense that they have to struggle to overcome the effect of the pink root and at the same time attempt to produce a marketable bulb—an effort which frequently fails.

Other Factors which Favor Pink Root. Sudden freezes during the fall or winter months or a sudden drought due to an unavoidable breakdown of the irrigation plant will invariably result in further weakening of the plants and the breaking down of the natural resistance. Any shock which will set back the onion plant will only increase its susceptibility to pink root. From a practical consideration, therefore, the only appreciable way of assisting infected green sets to overcome the disease is to encourage rapid growth so that new roots may be formed faster than they will be destroyed by the disease. Wherever possible, it is best, of course, to start with a healthy soil and healthy sets. It is useless to waste time and money in trying to nurse diseased green sets when they are planted in a diseased soil.

Poor Leveling. Repeated field observations have shown that wherever infected soil in the seed-bed or in the beds of the main crop is not properly leveled—a condition which prevents the even distribution of water—there will be a greater prevalence of pink root in spots. Improper leveling results in numerous high spots where water cannot reach the plants. The latter, therefore, become weakened as a result, and are severely susceptible to pink root.

Irrigation. It is very essential from the point of view of preventing pink root to encourage a vigorous and rapid growth of the plant once it has been set out in the field. A vigorous young onion set when transplanted in the field will develop new roots within three days after being transplanted, provided that the soil contains sufficient moisture and plant food. This means that it is imperative that irrigation should immediately follow the transplanting of the sets. There is, of course, no danger of losing plants from a slight delay in watering after the setting out of the young onions. However, an appreciable delay in irrigation immediately after transplanting will decidedly delay the formation of new roots and will result in a more severe pink root infection.

Weather Conditions. It is a known fact that weather conditions have a direct influence on the spread or limitation of pink root. While it is desirable to plant seedbeds early, this should not be done too early in the season. On the other hand, too—late sowing is likewise undesirable, because, as a result of it, the main crop will have to make most of the growth of bulbing during the hot weather. A check in growth brought about by freezing, delaying bulbing and maturity into the season of hot weather, is equally favorable to pink root development. Onion fields become badly infected where onions are grown continuously on that land during the entire year. This is often done when an attempt is made to supply the local market with green onions. The profits derived from the local market are hardly justified in the losses which are to follow from badly infecting the land. The best practice is so to manage the crop that it matures and is ready to be harvested before the hot weather strikes it.

Eel Worm. Eel worm, as stated on page 223, is a tiny microscopic worm (Fig. 10, E and F) which causes a disease known as root knot. This is manifested as swellings on the roots. It is believed by some growers that eel worm causes pink root. This, however, is not true. If one plants onions on lands which are infected with the eel worm but in which the pink root disease has never occurred, the onions, although becoming infected with the root knot, will not show any trace whatsoever of pink root. While it is certain that the eel worm does not cause pink root, it invariably opens the way to pink root infection (1) by weakening the plants and (2) by wounding the roots and thus opening the way for infection. It is, therefore, highly imperative that sets infected with pink root should never be planted on soil infested with eel worm.

Thrips. Like eel worm, thrips are not the direct cause of pink root. They merely weaken the plants and hence indirectly prepare the way for the disease. When young plants or onion plants of any age are attacked by large numbers of thrips, the vitality of these plants is decidedly reduced and they frequently die or produce undersized and unmarketable onions, even though the crop grows in otherwise healthy soil. If in addition to the thrip injury, the soil is also infected with the pink root organism, the result will usually be disastrous, since in this case the infected plants have neither root to afford support nor top growth to supply vigor. This means that an attack of thrips on onions grown on diseased pink root soil is invariably disastrous. In this case it is practically useless to attempt to save the crop; spraying or dusting would be time and money wasted. In practice, it has been repeatedly demonstrated that if a soil is free from pink root, if it is well supplied with rapidly acting fertilizers, and if, at the same time, the plants are thoroughly sprayed or dusted early to hold down thrips, other things being equal, the chances are for a good yield. On the other hand, when the plants are grown on a pink-root-infected soil which is deficient in humus, no amount of treatment to destroy thrips will help the infected plants to regain their vigor and produce a normal yield.

Where the onion grower is compelled, for lack of sufficient acreage, to grow his onion crop on pink-root-infected soil, every precaution should be taken not to allow the thrips to get the upper hand. Here spraying

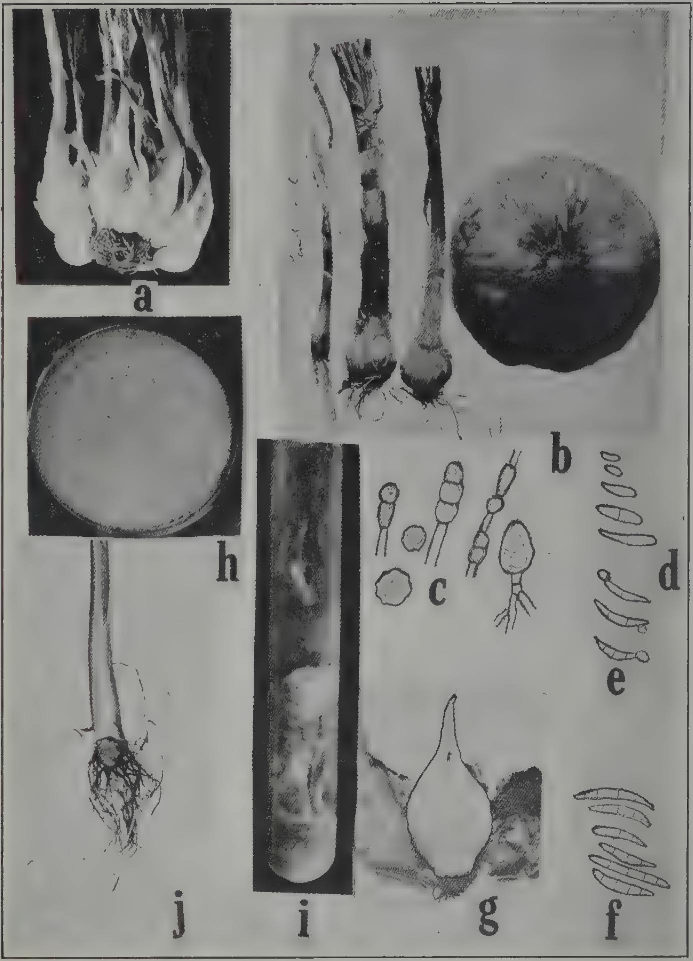

FIG. 12.

a. Pink root of shallot, showing destroyed root-system and nipple formation. *b.* To right, normal mature onion; to left, extreme case of onions affected by pink root. *c*, *d*, *e* and *f*. Chlamydospores and macroconidia of *Fusarium malli*. *g*. Fusarium rot of onion confined to outer scales of bulb, and different from pink-root disease (*g* after Clinton.) *h*. Plate culture and *i*, Tube culture of *F. malli*. *j*. Longitudinal section through onion plant affected with pink root showing nipple area and dead roots.

or dusting should be carried out early and repeatedly, and as soon as the thrip appears. For control methods for thrips, see page 228.

Soil Temperature. There seems no doubt that the soil temperature has a decided influence in favoring pink root disease. The trouble usually reaches its maximum at about harvest time. At that time, which in Texas occurs during April and May, the soil temperatures are higher than at any other time during the active growing season of the onion crop. In this connection, one should keep in mind that frequent watering during the bulbing period will greatly encourage rapid growth and tend to keep the soil fairly cool. When planting is done late, everything possible should be done during the hot months of the year to reduce the soil temperature several degrees just preceding the bulbing period. This, of course, is accomplished mainly through irrigation. Any break in the pumping plant at that time would be most critical.

The Organism. Pink root of onions, as already stated, is caused by a fungus technically named *Fusarium malli* Taub. in honor of the junior author. It is very likely true that in various states where pink root occurs other species of Fusaria may be involved in causing the disease. In Texas, *Fusarium malli* has proved to be the cause of pink root, although other Fusaria are frequently associated with it. The spore (Fig. 12, D and E) measurements of *F. malli,* especially the macroconidia, seem to be greatly influenced in size by the media on which the fungus grew. The largest-sized spores seem to be obtained on hard bean agar (Fig. 12, H) and the smaller ones on potato plugs (Fig. 12, I). Furthermore, microconidia are apparently formed on hard bean agar only. Of the macroconidia, the three-septate type seems to predominate. Only about 2 per cent of the spores are four-septate. Five-septate spores are rare. On potato plugs, pionnotes are numerous and assume the color and consistency of butter, thus distinguishing it readily from *Fusarium oxysporum* of the Irish potato, which only has pseudo-pionnotes. *F. malli* produces few or no sclerotia and very little color on starchy media. However, on potato plugs the color varies from slightly greenish to purple. Chlamydospores (Fig. 12, C) are abundantly produced, both terminal and intercalary.

Methods of Control. So far no practical method was found which could be used in treating infected sets. Any treatment which would be effective in killing the causal organism in the diseased roots would at the same time injure the green set, either in reducing germination and growth, thereby increasing the susceptibility to pink root or in killing outright the green sets. The disease is best controlled by the three following methods:

Soil Sterilization. From what has been said on page 185, it is clear that the causal organism is carried in the soil of the seed-bed and from there into the soil of the main field. The first attempt, therefore, should be to sterilize the seed-bed soil. This may be accomplished in two ways: first, the soil may be treated with formaldehyde at the rate of one pint of the chemical to twenty gallons of water; second, the soil may be steamed for a length of time sufficient to cook a raw potato. Both of these methods will prove effective. In treating the seed-bed soil with formaldehyde, one proceeds as follows: The seed-beds are prepared in the usual way with the exception that they are made to average not more than eight feet in width. As the bed is being flooded, a quantity of 40 per cent formaldehyde is placed in a container and allowed to drip into the water as it enters from the ditch through the cut in the border. Dripping is so regulated that it will fall at the rate of one pint of the formaldehye to twenty gallons of water. It is safest to carry out the formaldehye treatment after the last preparation of raking, harrowing, and leveling of the seed-bed. This means from five to eight days before sowing the seed. Under normal prices, it is possible to use formaldehyde to disinfect large acreages of seed-beds.

Steam sterilization is only possible where means are at hand for a good steam boiler with a good pressure. The method of steam sterilization is the same as that employed for the sterilization of soil recommended for other plant diseases and known as the "inverted pan" method. This method was first used by Shamel for sterilizing nematode-infested soil in Florida. A galvanized iron pan 6 feet by 10 feet by 6 inches deep is inverted over the area to be sterilized after it has been prepared for seeding. As the edges of the pan are sharp, they can be readily pressed into the soil to the depth of one inch or more, thus forming a tight compartment under the pan, into which the steam is run from 30 to 60 minutes. The steam is generated by a boiler with a pressure of 50 to 180 pounds. The time of steaming depends upon the type of the soil and its compactness and moisture-content. The pan could be made 12 feet in length without losing any efficiency. This is especially true in the case of large boilers. It is best to place the handles of the pan on the side instead of on the ends. In this way the pan may be moved from one section of the bed to another without the operator's walking on the sterilized soil and hence reinfecting it. The weight of such a pan is approximately four hundred pounds. A one-inch steam hose is used to connect it with the boiler. A traction engine such as is used for thrashing is most convenient to furnish the steam. Considering the present high cost of formaldehyde (unless prices should be considerably reduced in the future), the grower should try, wherever possible, to use new land for the seed-beds, bearing in mind the importance of producing healthy sets and of sparing them the unnecessary struggle to overcome the disease. As to field methods of control, it is of course out of the question to try to sterilize the soil either with formaldehyde or with steam. The efforts of the grower should, therefore, be to grow the main crop on new land if that is possible. Whether new land or diseased land is used, every effort should be made to secure for the general field only healthy sets which were previously raised in healthy seed-bed soil.

Use of Fertilizer. By using the proper kind of fertilizers and by attending to the general cultural considerations as well as irrigation, one may under Texas conditions obtain a normal crop on diseased land, provided healthy sets are used at the start. Where one is compelled to use pink root infected sets and infected soils, the only hope of obtaining a commercially profitable crop would consist in the ability of the grower to supply quickly available plant food in quick succession. This will mean that the plants will be kept vigorous enough to enable them to produce new rootlets as quickly as diseased ones die, or even more quickly. By this method the crop, especially under Texas conditions, will go on through the winter season, reach the bulbing stage, and have a fair chance to produce marketable-sized onions. This means that it is advisable and necessary to use fertilizer on pink-root-infected land to obtain any crop at all. As a general guide, it might be stated that for the average soil infected with pink root and under Texas conditions, it is necessary to use fertilizer not less than 1000 pounds per acre, and of a brand which shows an analysis of about eight per cent of acid phosphate, four per cent nitrogen, and four per cent of potash. In addition to the above fertilizer, applications of nitrate of soda should be given at intervals during the growing season. For purposes of best results, the complete fertilizer should be added about thirty days ahead of transplanting time and should be well worked into the soil. Soon after the green sets are transplanted from the seed-bed to the main field, and after they have become well rooted and started growing, it is advisable to apply the first amount of nitrate of soda to the extent of about 100 pounds per acre. The second application of nitrate of soda should be given in like amount about the middle of February, provided of course the crop shows need of it. The third and last application of nitrate of soda is given about March first at the rate of 100 pounds per acre. From this it would appear that one heavy application of a complete fertilizer, and three of nitrate of soda are to be recommended for pink-root-infected soils in which pink-root-infected green sets have been used. It should, however, be understood that such recommendations are given only to Texas growers who are unable to secure healthy plants or who, for the most part, must depend on pink-root-infected sets as well as diseased soil. It should not be forgotten, however, that the use of nitrate of soda will promote rapid, tender growth, and that such plants may suffer severely from sudden frost or drouth, as happens in case of a sudden breakdown in the irrigation plant. This element of risk, however, is not so great in the final result as it is in taking a chance of producing a profitable crop on a pink-root-infected soil which lacks humus or quickly-available plant food. There is no doubt but that soils deficient in humus are doubly unfit for onions —first, because they favor pink-root development; second, because they fail to promote rapid growth, hence encouraging a greater susceptibility to the disease. Furthermore, such soils also fail to take up the usual amount of irrigation water, an excess of which is unfavorable to the crop. In other states where pink root is becoming serious, the use of fertilizer will, of course, have to be worked out, depending on the particular soil, climatic conditions, cultural practices involved and whether the crop is to be sold early or stored during the winter months. In each case, however, the thing to keep in mind is the stimulation of a rapid growth in order to overcome the ill effect of the disease.

Rotation of Crops. Field observations tend to show that rotation of crops is beneficial in reducing the amount of pink root, although such a practice does not eliminate altogether the causal organism. Those counties in Texas which practice a system of crop-rotation suffer less from pink root than those in which onions are grown successively for a period of years on the same land. It is popularly believed that onions are the one crop that can be grown continuously on the same land for a number of years. This may be true, provided all disease is kept out and the fertility of the soil is maintained by applying manure and plowing it under. Great danger, however, lies in the fact that when onions are grown too long on the same land the pink root disease may sooner or later be introduced. When one starts with a virgin land, it is advisable not to grow onions for more than three consecutive years, even though healthy sets are always used. In this case a two-year rotation every third year during which no onions or garlic are grown is strongly recommended for lands free from pink root. In dealing with infected soils, the grower is urged to adopt a four-year rotation without onions before he can reasonably expect anything like a normal yield.

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FUSARIUM ROT

Caused by *Fusarium sp.*

In 1915 onions in some states rotted badly from a Fusarium fungus. In many instances the growers lost one-half to three-fourths of their crops. The rot seemed to affect the bulb only, working down between the layers of the scales, often rotting one or more, so that the outside easily slipped off while the inner layers remained healthy (Fig. 12, G). It is claimed that the wet season of 1919 in Connecticut was chiefly responsible for the development of this trouble because most of the bulbs were largely infected in the field and before they entered the storage house. In Ohio this same rot also seemed to prevail that year, and is now considered a serious field disease.

Control. Very little is known about this form of rot and still less about the causal organism. This trouble should not be confused with the pink root disease, the latter of which attacks the roots only, and has never been found to attack any other parts of the bulb as is the case with the Fusarium rot. Methods of control should therefore be confined to selecting the bulbs carefully before they enter storage. Where the disease is suspected to be present in the field, several handfuls of representative samples of the onions to be stored should be cut open and examined for the Fusarium rot. If a large percentage of them show evidences of the disease, no attempt should be made to store them.

YELLOW LEG

Caused by Fusaria and Bacteria

Yellow leg is quite common in Connecticut, and is found troublesome on fully-grown onions which have not been fully matured. Occasionally stalks are affected, thus turning yellow below and finally dying before full maturity of the seed. Such stalks are readily pulled out from the ground, as the main roots and bulbs have largely rotted off. Fusaria and bacteria are usually found associated with this rot; although more work is necessary to determine definitely the cause of the trouble, and practical methods of control.

CHAPTER XIX

White Mold

Caused by *Sclerotium cepivorum* (Berk.)

This disease is prevalent in England and it is different from the neck rot (*Botrytis allii*) which occurs in the United States. The disease was first described by Berkeley in 1841. It was later found in Italy by Voglino in 1902. In 1920 Cotton gave it a thorough study as it occurs in England. This disease is merely mentioned here with the hope of calling it to the attention of our American onion growers so that proper steps may be taken to prevent its introduction.

Symptoms. The disease begins by attacking individual plants indiscriminately in the field or in the seedbed. The trouble manifests itself as a wilting and yellowing of the foliage. The oldest leaves usually become yellow and fall over. When the infected plants are pulled out, it is noticed that the seat of the trouble is localized mostly on the roots and from there the disease progresses to the bulb (Fig. 7, A). It seems that white rot is most prevalent during warm, damp weather. Badly diseased bulbs have a white appearance due to the mass of white fungus threads which grow on them. It is this white mycelium which gives the disease its name of white rot and at once distinguishes it from other diseases of the onion. After the bulb becomes thoroughly rotted, most of the white mycelial growth disappears and gives place to numerous minute sclerotia the size of a poppy seed. It is these sclerotia which remain in the ground and help to carry over the causal fungus from year to year. In England white rot first appears in June and continues until early August. By that time most of the affected plants are destroyed and very few new infections appear to take place after that date.

The Fungus. Sclerotium cepivorum produces sclerotia, which upon germinating give rise to ordinary vegetative mycelium threads, the latter of which produce minute conidia or micro-spores known as *Sphæcleia.* It is thus seen that this fungus does not produce a Botrytis stage, a characteristic which at once distinguishes it from *Botrytis allii,* the cause of neck rot. It seems that the disease spreads from field to field through particles of dirt which contain the sclerotia of the causal fungus. These sclerotia may be further carried about with implements and on the feet of the workers.

According to Cotton, white rot attacks practically all the common varieties of onions. It seems that shallots are decidedly resistant, since they are able to grow side by side with onions without contracting the disease. Leeks, too, seem to be considerably resistant to white rot.

Distribution. In England white rot seems to be widespread in gardens, market gardens, and private estates. It doubtless occurs in all parts of England. It is also found in Edinburgh and Dublin. It is very serious in gardens near London and near Manchester.

Control. No hope is ever held out for controlling this disease by the use of soil fungicides. Perhaps the only method of control would be crop rotation, which would give the land a rest from onions for several years so as to starve out the causal organism.

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Fungi Parasitic on Members of the Genus Allium. This list is merely given with a view of calling attention to the parasitic fungi which occur on various members of plants which are closely related to the onion. Many of these fungi are not, as yet, known to attack the cultivated onion. However, there is no telling how soon they will attack it and become of economic importance. This list, therefore, should help the student and the alert grower to be on the lookout for any new parasites which may attack the onion crop.

LIST OF FUNGI PARASITIC UPON MEMBERS OF THE GENUS ALLIUM

Name of Fungus	Name of Host
Aecidium allicolum Wint.,	*Allium stellatum*
" *convallariæ Schm.,*	" *reticulatum*
" *reticulatum Thm.,*	" *victoriale*
Acrothecium melanopus (Sz.,) Sacc.,	" *cepa*
Cæoma (Uredo) alliorum Lk.,	" *cepa, porrum, etc.*
Cercospora victorialis Thm.,	" *victoriale*
Cladosporium sparsum Sz.,	" *cepa*
" *fasciculare (Pers.) Fr.,*	" *sp.*
Darluca aschochytoieds Sacc. and Roum.,	" *ampeloprasum*
Fusariella atrovirens (Berk.) Sacc.,	" *sps.*
Heterosporium allii E. and M.,	" *vineale*
" " *var. allii-porri, Sacc. and Br.,*	" *porrum*
" *ornithogali Klotsch.,*	" *vineale* (?)
Macrosporium cladosporioides Desm.,	" *sp.*
" *porri Ellis,*	" *porrum*
" *punctatum Kalch. and Cke.,*	" *schoenoprasum*
" *vesicarium (Wallr.) Sacc.,*	" *sativum*

Name of Fungus	Name of Host
Mucor subtilissimus Berk.,	*Allium sp.*
Mystrosporium alliorum Berk.,	" *sp.*
Perisporium exuberans Fr.,	" *sp.*
Phoma alliicola Sacc. and Roum.,	" *sp.*
Phyllachora cepæ (Sz.) Sacc.,	" *cepa*
" *penicillata (Sz.) Sacc.,*	" *sp.*
Pleospora allii (Rabh.) Ces. and DeNot.,	" *cepa, porrum*
" *cepæ (Preuss.) Sacc.,*	" *cepa*
" *socialis Niessl. and Kunz.,*	" *cepa*
Puccinia allii (DeC.) Rud.,	" *sativum, etc.*
" *mutabilis Ell. and Gall.,*	" *mutabilis*
" *porri (Low) Wint.,*	" *cepa, porrum, fistulosum*
" *sessilis Schn.,*	" *ursinum*
Rhizoctonia allii Grev.,	" *ascalonicum*
Saccharomyces allii Sor.,	" *cepa*
(Sclerotium ceprivorum Berk.),	" *cepa*
Scolecotrichum diplodioides (Thm.) Sacc.,	" *neapolitanum*
Septoria alliacea Cke.,	" *sp.*
" *allicola Baum.,*	" *flavum*
" *alliorum west.,*	" *porrum*
" *viriditingens Curt.,*	" *tricoccum*
Sphaerella allicina (Fr.) Auers.,	" *sp.*
" *schoenoprasi Auers.,*	" *porrum, etc.*
Torula allii (Harz.) Sacc.,	" *cepa*
Urocystis cepulæ Frost,	" *cepa*
" *colchici (Schl.) Rabh.,*	" *sp.*
" *magica Pass.,*	" *magicum*
Uromyces aculeatus Fckl.,	" *victorialis, etc.*
" *ambiguus (DeC.) Fckl.,*	" *scorodoprasum*
" *erythronii (DeC.) Pass.,*	" *victorialis, etc.*
" *vernalis Speg.,*	" *striatellum*
Vermicularia circinans Berk.,	" *cepa*
" *dematium (Pers.) Fr.,*	" *cepa*
" *liliacearum S.,*	" *sp.*
" *schoenoprasi Auers and Fckl.,*	" *schoenoprasum*

Occurrence of Spores on Onion Seed. The practical grower would, of course, like to know whether or not onion seed carry spores of parasitic fungi. This is important to know when we are considering the possibility of disinfecting the seed before sowing. Anyone who has had experience in germinating onion seed in the laboratory in agar plates will know that, no matter what precautions are taken, some organisms will develop in the agar media. Many of these are either carried as spores on the surface of the seed or internally as mycelium. Spores of *Urocystis cepulae* may be carried on the surface of onion seed. The same is also true for spores of downy mildew, *Peronospora schleideniana,* brown mold, *Macrosporium porri,* and numerous spores of Penicillium and Mucor. With the exception, perhaps, of the latter two, neither the Urocystis, nor the Macrosporium, nor the Peronospora will actually inhibit germination of the seed. Nevertheless, such spores when introduced in the field in a fresh condition may cause serious trouble to the main crop. When the formaldehyde drip is used, many of these spores of parasitic fungi will naturally be destroyed, so that it will not be necessary to treat the onion seed with any kind of disinfectant.

DODDER

Caused by *Cuscuta sp.*

Ordinarily dodder is not found to attack onions. However, there are instances in which dodder was known to attack onions in Stockton, California, in 1919; in Racine, Wisconsin, in 1920; in Walla Walla County, Washington, in 1919; and in Lansing, Illinois, in 1920. In the first two instances little damage was noticed. However, in the last the dodder has caused great damage to onion sets. In the infected patches the tops of the plants have been completely killed, as a result of which the bulbs were decidedly undersized. The dodder appeared first in one or two centers of the field when the onions were about two inches high. On these spots it had spread by the cultivators and various implements used in the fields. Considering the fact that onions are usually planted very close, the crop requiring constant cultivation, it is very easy to spread dodder in any one given field unless the proper measures are taken to eradicate it. The dodder (*Cuscuta sp.*), a dangerous native weed is a slender, yellowish, leafless, vine-like plant. It bears irregularly-shaped clusters of yellowish flowers and later light brown smooth pods varying from one-eighth to one-quarter of an inch in diameter, each pod containing one to four seeds. The seeds are about the size of small red clover or alfalfa seeds, tan or brown in color, rounded on one face and flattened on the others where they fit together in the pod. The seeds are rough and may be taken for sand.

The plant is an annual. In other words, it starts growth from a seed in the spring, produces seed, and dies all in one season. The seeds germinate and send up a hairlike shoot with an enlarged tip. If the air currents bring this tip into contact with another plant, it fastens itself there and severs its connection with the soil. The plant to which the dodder fastens itself is called the "host" because through small "suckers" on the rapidly growing stem the dodder gets all its nourishment from the plant which it attacks.

Having established itself on the host, it grows rapidly because none of its energy is required to produce its own food. It branches freely, the branches attaching themselves to new hosts and often severing their connection with the mother plant. Robbed of its food, the host soon dies and the dodder dies with it, but not before many or all of the dodder seeds are ripe. The yellow patches change to brown and grow constantly larger and, unless measures are taken to destroy the dodder, much of the crop will be lost.

Control. As is the case with dodder attacking other crops, it is essential to dig out and burn infested spots so as to prevent the spread of the dodder. Furthermore, it is very likely that the dodder seed are produced with the onion seed. Therefore, where one suspects the seed of containing dodder, they should be carefully screened and the plants watched as they come up for presence of dodder. It is not likely that dodder will become a serious pest wherever careful methods of control are employed.

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CHAPTER XX

Storage Rots

Since the largest profits are derived when onions are sold during the time of greatest demand, it is necessary to store a portion of the crop. This is especially carried out with onions grown in the northern states. Some of the most serious storage rots have been described on page 201. Here, then, we shall concern ourselves with the best practical storage methods so as to reduce to a minimum the losses from storage rots. Perhaps the most critical period exists during several weeks between harvest and storage or even shipment. It is usually at that time that the greatest amount of disease develops in the warehouse or even in transit. Therefore, the care which is given to the crop at this time may result in a difference between profit or failure. In the field, onions intended for winter storage should be allowed to ripen well. The degree of ripening is usually indicated by a dying of the tops and a softening of the necks of the plants so that the tops begin to fall over. Furthermore, the outer skin of the bulb becomes dry before being pulled. Where the onions are planted late and the season advances, the ripening process may be hastened by using a light roller so as to break the tops. After being pulled, the onions are allowed to lie in the rows for several days. At that time they are occasionally stirred with garden rakes so as to encourage even drying of the bulbs. This is called the "sweating period" preparatory to storage or shipment. After the necks are clipped off, the bulbs are put in crates and are either allowed to dry in the field or are carried to the curing sheds, where the crates remain for about two weeks before finally entering storage. This method is favored by most growers as it is not always desirable to expose the red and yellow varieties to full sunlight in the field. The immature, soft, or "thicknecks" should not be stored, as they will generally keep very poorly. When the onions rattle like wood blocks when poured out of the crate, they are said to be ready to go to storage.

After curing in the sheds, the bulbs are re-sorted in a sorting rack, and only the sound ones should find their way to the storage room. In some localities onions are stored in pits like sweet potatoes. While this method may be fairly desirable on a small scale, it is of course out of the question on a large scale of storage. Ordinarily, when the weather remains warm and dry during harvesting and curing, it is safe to add that the crop will keep well in storage. However, if the prevailing weather is rainy, heavy losses from rots are to be looked for in storage. Under these conditions, the bulbs cannot properly cure or "sweat," and the excess of moisture retained will be later favorable to the development of the various storage rots already mentioned.

Usually onion tops and rotted bulbs and onion refuse from the storage house when dumped into the field will serve an excellent starting point for many of the fungi and bacteria to cause rot on onions. No onion refuse, whether tops or decayed material from the storage house, should ever be dumped in the field, nor should it ever be left in a pile near the warehouse. A pile of rotted onions near a storage house may under proper conditions of wind currents carry infection to the near-by fields. After harvesting, all refuse should be either raked and burned or, still better, plowed under very deep. Waste from the storage house when spread in the field should be put on land where onions will not be grown for a long time.

Where the crop matures unevenly, it is best to postpone harvesting until the majority of the plants show definite signs of ripening. Frequently heavy rains previous to harvesting may postpone ripening, as a result of which there is an over-production of "stiff-necks" or "scallions." In this case cutting the roots with a wheel hoe will tend to hasten maturity. In clipping the tops, a one-inch neck should be left. This will avoid exposing the succulent tissue of the bulb to infection. Extreme care should be exercised in harvesting so as to prevent unnecessary bruises, as they will open the way, no doubt, to many forms of rots.

As the onions are being sorted out, all those bulbs which show the least sign of disease or insect injury should be discarded. Bulbs which have been injured in the field by either smut or mildew will readily rot in storage because of the infection of secondary organisms. However, as far as Fusarium rot (see page 199) is concerned, this disease gains a foothold in the field and merely continues slow destructive work as the bulbs enter storage. During harvesting, if the weather is damp and rainy, it is necessary to keep a sharp lookout for soft rot and neck rot, which may start in the field. The construction of the storage house determines in a large measure the keeping quality of the crop.

A successful storage house should consist of a number of thicknesses of lumber and contain one or more dead air spaces. It should be remembered that in the northern states where most of the onions are stored, the storage houses should be built so as to facilitate the keeping of the temperature slightly above 32° F. during severe winter weather; maintaining as little artificial heat as possible is advisable. On the other hand, ample provision should be made for a large amount of ventilation, because the bulbs, even after curing, continue giving off considerable moisture which must be removed. This means that on bright clear days, all doors and windows should be kept open for at least a few hours during the day. During exceedingly cold weather, to prevent the onions from freezing, the storage house should be heated by any kind of convenient heat. Either steam, hot water, or ordinary stoves placed at intervals in the house will answer the purpose. When large bulbs are stored, it is preferred to put them in standard bushel boxes or folding crates. However, sets should be placed in two- to four-inch deep shallow crates. On a small scale the bulbs may be successfully kept in an ordinary dry cellar where the temperature may be maintained all the winter at 32° to 35° F.

Frequently the construction of an onion storage house is not different from that of an up-to-date sweet potato house. Such a structure is double-walled throughout, with a dead air space constructed with plenty of felt or paper lining. In this way, the dead air spaces in the wall permit a more even indoor temperature distribution. Top ventilation is provided by means of roof ventilators. Bottom ventilation is secured by means of bottom windows or large drain pipes built into the foundation at the surface of the ground.

A false floor inside, leaving an air space of about two to four inches from the main floor, will assist considerably in the air circulation. Occasionally onions are stored either in bags or in slatted bins with a capacity of 100 to 300 bushels each. This method is not conducive to very good keeping. As already stated, it is best to store in crates.

On the Pacific coast and in many of the northern states where globe onions are grown extensively, it should be remembered that both the red and yellow varieties are more resistant to rots in storage than are the white varieties. The white varieties are especially subject to smudge and neck rot in storage. This means that they require unusual care during harvesting and curing. Certain white varieties, like the Queen, Pearl, and Berleeta, are such poor keepers that they are seldom held in storage. These, if grown, are sold immediately after harvesting. The same is true of the white Bermuda, mostly grown in regions of Texas, southern California, and Louisiana, where the crop is always disposed of on the early markets, soon after harvest. This is due mainly to their poor keeping quality and a lack of cold storage facilities in these states. Furthermore, as is the case in Texas, it pays the growers to dispose of the crop at a very early date in the early summer when new onions are in demand and they bring reasonably good prices, depending on the year. In Louisiana the variety Creole is said to be much more resistant than the Bermuda; hence keeps better in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN TRANSIT

Assuming that we are able to ship onions in a healthy condition as they leave the field, there is still the big factor of controlling heavy losses from rots as they occur in transit. Of course, the grower is not directly interested in these losses inasmuch as they practically concern the buyer and produce-man. However, for his own benefit the grower should be interested in the onion crop, not only so far as concerns the disposal of it from the field, but he should also have a share in helping to reduce losses from rots in transit. This will mean a better reputation for his product and in turn a better demand for it in the market. There seems no doubt but that when buyers find out that onions bought from certain localities rot worse in transit than those bought from other localities, they will eventually avoid those localities which always cause them heavy money losses. The diseases which are responsible in destroying parts of the onion crop as it is shipped in transit are practically those which are found in storage. They may be mentioned as follows: Neck rot, described on page 169; soft rot, described on page 119; smudge, described on page 131. In order to more forcibly emphasize the importance of losses from onion rot in transit, Table 17, which gives estimates of inspection at the various market destinations, speaks for itself.

Table 17 contains results of inspections for 1918 only. Space is too limited to permit the inclusion of available data for other recent years. From Table 17 it is seen that the three principal transit rots which are of greatest economic importance are soft rot, neck rot, and black mold. While it is important that the grower

TABLE 17

Losses from Onion Diseases in Transit

Place of Origin	*Date and Place of Market Inspection*	*No. of Cars Inspected*	*Kind of Rot*	*Name of Fungus*	*Per Cent Loss*
California	July 1, 1918, Minneapolis	1	Neck rot	Botrytis allii	5–40%
California	Sept. 1, 1918, Kansas City	1	do.	do.	100%
California	Nov. 1, 1918, St. Paul	1	do.	do.	10–15%
Florida	July 1, 1918, Kansas City	1	do.	do.	2%
Illinois	May 15, 1918, Chicago		do.	do.	9%
Illinois	Sept. 1, 1918, Chicago	2	do.	do.	2%
Illinois	Nov. 1, 1918, Boston, Pittsburgh	2	do.	do.	3%
Kentucky	Sept. 1, 1918, New York	3	do.	do.	2%
Louisiana	Nov. 1, 1918, Cincinnati, Pittsburgh	2	do.	do.	2–3%
Massachusetts	May 15, 1918, New York	4	do.	do.	4%

Massachusetts	May 15, 1918, New York	4	do.	do.	25%
Michigan	May 15, 1918, New York	2	do.	do.	8%
Michigan	May 15, 1918, Cleveland	2	do.	do.	5%
Missouri	May 15, 1918, St. Louis	4	do.	do.	20%
New York	July 1, 1918, New York	1	do.	do.	8%
Ohio	May 15, 1918, Kansas City	2	do.	do.	2%
Ohio	May 15, 1918, New York	2	do.	do.	2%
Pennsylvania	July 1, 1918, Boston	1	do.	do.	1%
Texas	July 1, 1918, Houston, Cincinnati	3	do.	do.	3-4%
Texas	July 1, 1918, Boston, Kansas City	2	do.	do.	4%
California	July 15, 1918, Chicago	1	Black mold	Aspergillus niger	7%
California	Sept. 1, 1918, Chicago, Kansas City	2	do.	do.	2%
California	Nov. 1, 1918, Boston	6	do.	do.	6–20%
Illinois	July 1, 1918, Baltimore	2	do.	do.	11%
Illinois	July 1, 1918, Philadelphia	2	do.	do.	22%

TABLE 17—*Continued*

Place of Origin	*Date and Place of Market Inspection*	*No. of Cars Inspected*	*Kind of Rot*	*Name of Fungus*	*Per Cent Loss*
Illinois	Sept. 1, 1918, Chicago, New York	3	Black mold	Aspergillus niger	15–30%
Illinois	Nov. 1, 1918, Detroit, Pittsburgh	2	do.	do.	2–50%
Missouri	July, 1, 1918, Baltimore, New York, Philadelphia	4	do.	do.	3, 5, 7, 11%
Pennsylvania	July 1, 1918, Boston, New York, Philadelphia	4	do.	do.	5–50%
Texas	July 1, 1918, Boston, Buffalo, Cleveland, Kansas City, Milwaukee, Newark, New York, Philadelphia, Pittsburgh, St. Louis, Wilkes-Barre	30	do.	do.	20%
Texas	July 15, 1918, Boston, Chicago, Kansas City, New York	10	do.	do.	18–60%
Texas	Sept. 1, 1918, Baltimore, Buffalo	3	do.	do.	5–32%
California	July 1, 1918, New York	1	Soft rot	Bacillus caratovorus	4%

California	July 15, 1918, New York, Chicago	2	do.	do.	2–15%
California	Sept. 1, 1918, Chicago, Kansas City	6	do.	do.	5–30%
California	Nov. 1, 1918, Boston	1	do.	do.	6%
Illinois	May 15, 1918, New Orleans	3	do.	do.	7%
Illinois	May 15, 1918, Minneapolis	3	do.	do.	25%
Illinois	May 15, 1918, St. Louis	3	do.	do.	28%
Illinois	July 1, 1918, Philadelphia, Pittsburgh	4	do.	do.	30%
Illinois	Sept. 1, 1918, Chicago, New York	12	do.	do.	5–8%
Illinois	Nov. 1, 1918, Detroit, New Orleans, Pittsburgh	5	do.	do.	6–30%
Iowa	Nov. 1, 1918, New Orleans, Philadelphia, Pittsburgh	5	do.	do.	6–20%
Iowa	Nov. 1, 1918, New Orleans, Philadelphia, Pittsburgh	11	do.	do.	25%
Kentucky	May 15, 1918, New York	2	do.	do.	3%
Kentucky	May 15, 1918, Ft. Worth	2	do.	do.	13%
Kentucky	Sept. 1, 1918, New York	2	do.	do.	2%

TABLE 17—*Continued*

Place of Origin	*Date and Place of Market Inspection*	*No. of Cars Inspected*	*Kind of Rot*	*Name of Fungus*	*Per Cent Loss*
Kentucky	Nov. 1, 1918, New Orleans, Pittsburgh	1	Soft rot	Bacillus caratovorus	15%
Louisiana	Sept. 1, 1918, New York	1	do.	do.	39%
Michigan	May 15, 1918, Cleveland	2	do.	do.	16%
Michigan	May 15, 1918, New York	2	do.	do.	5%
Minnesota	Sept. 1, 1918, Baltimore, New Orleans	2	do.	do.	15–40%
Missouri	July 1, 1918, Philadelphia	2	do.	do.	7–8%
Missouri	Sept. 1, 1918, New Orleans	215 sacks	do.	do.	15%
New York	May 15, 1918, Buffalo	2	do.	do.	3%
New York	Sept. 1, 1918, New York	1	do.	do.	3%
North Carolina	July 1, 1918, New York	2	do.	do.	20%
Ohio	May 15, 1918, Baltimore	4	do.	do.	2%

Ohio	May 15, 1918, Boston	4	do.	do.	20%
Rhode Island	Nov. 1, 1918, Boston	1	do.	do.	10–50%
Texas	July 1, 1918, Cincinnati, Baltimore, Kansas City, Milwaukee, New York, Passaic, Philadelphia, Pittsburgh, St. Louis	34	do.	do.	20%
Texas	July 15, 1918, Chicago, Kansas City, New York	7	do.	do.	24%
Virginia	Nov. 1, 1918, Providence, Pittsburgh	8	do.	do.	6–10%
Washington	Nov. 1, 1918, Philadelphia, Pittsburgh	4	do.	do.	12%
Florida	July 1, 1918, Jacksonville	153 sacks	Watery soft rot	Sclerotinia libertiana	2%

himself be interested in helping to control losses from onion diseases in transit, yet this problem equally concerns the commission man and the man in the market as well as the railroad employee. These men should realize that it is the fungi which steals from their profits, not to mention the fact that the consumer has to pay for it in the long run. The consumer is usually very patient when taxed with high prices, but a certain stage is reached where he simply boycotts the product and refuses to buy. When this condition is reached, the farmer and the produce-man are both the losers. Before attempting to control losses in transit, it is necessary to ascertain the causes which help to bring about infection in the cars.

1. A large per cent of decay in transit is brought about directly by shipping diseased material to begin with. For instance, neck rot has been shown to be a field fungus. A few infected bulbs placed in a sack or in a car will, under proper conditions of moisture, spread and contaminate other bulbs, if they happen to be bruised or scratched. In this connection practically every onion bulb is bruised because, as we know, the tops of the plants are cut off, and such cuts present an ideal medium for any parasite to enter. Furthermore, careless manipulation in digging, topping, grading and packing may result in cuts and bruises which will open the way to soft rot, black mold, and even neck rot.

2. It should be remembered that onions are not as resistant in transit as they are when growing in the field; hence some organisms such as the black mold (*Aspergillus niger*), for instance, which ordinarily is not supposed to be a parasite, will readily attack onions as well as other perishable crops in transit on account of the fact that such products have lost their resistance.

It is to the advantage of the railroad man to prevent claims rather than fight them. Since most of the transit rots of the onion are due to organisms which ordinarily work in the field, the grower should be educated to be able to distinguish these parasites and to prevent their introduction into shipments with diseased material. Every possible care should be exercised in digging, topping, grading, and packing. All railroads should have a definite system of inspection, the inspectors having each a certain territory to look after and act as advisers to the growers. The Bureau of Markets, of the United States Department of Agriculture, is doing excellent work in this direction. This bureau has now established a system of inspection which goes a long way in protecting both the grower and the produce-man. More good could be accomplished through the railroads themselves by educating the shipper how to pack and load.

Mention has already been made of the need of care in packing. Whether hampers or sacks are used, it is essential that only one kind of container should fill up the car. In loading the onions, one should try to secure all the ventilation possible. This is accomplished by so spreading the crates, or sacks, as to allow the free circulation of air. At the same time, the space must not be too wide to permit shifting of the containers, and hence the bruising of the onions. Frequently and especially where onions are shipped long distances, it is advisable to put in a false floor in the car. This will result in a still better circulation of air. Occasionally, when onions are shipped in the middle of the winter, especially to some of the western states, it would be desirable to install a heater to prevent the onions from freezing. In general, it is advisable not to load a car solidly. The space in the doorway should be left for ventilation, and for a heater, if that is necessary. Onions shipped long distances naturally have to be provided with more ventilation than those shipped locally or short distances. In short, the whole problem of losses from decay in transit and their prevention needs to be investigated, and such investigations really should be carried out by competent Plant Pathologists of the various Agricultural Experiment Stations of those states in which onions form an important part in the system of agriculture.

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CHAPTER XXI

ANIMAL OR INSECT PESTS

Root Knot

Caused by *Heterodera radicicola* (Greef) Müll.

ROOT KNOT has been reported from Indiana and Texas, and is probably found in other states where this pest is known to attack other crops. The disease attacks the growing roots only and never the bulb itself. It is manifested as small white swellings or knots on the roots (Fig. 10, G). These occur singly, or there are many on the same root. When onions or other susceptible crops are grown on the same land for several years, it becomes impractical to grow a profitable onion crop on that land.

Cause. The cause of root knot is a little worm seldom exceeding $^1/_{25}$ of an inch in length. It is semi-transparent and because of its minuteness can be seen only when magnified under the microscope. There are two types of worm: one, the male, is cylinder-shaped; the other, the female, is pearly white and pear-shaped. The latter, especially, is firmly imbedded in the gall tissue of the root. The female is very prolific and deposits no less than 400 or 500 eggs during her lifetime. The eggs are whitish, semi-transparent, bean-shaped (Fig. 10, E), and too small to be noticed by the naked eye. In warm days the eggs hatch soon after they are laid. The young larvæ usually leave the gall tissue and hunt for new roots. The head of the worm is provided with a boring apparatus which consists of sharply pointed spears located at the mouth. This structure enables the worm to get its food as well as to batter through the cell walls of the root so as to gain entrance within the root tissue. During the first fifteen to twenty days of its life history, the sex can not be distinguished. However, during the last moult, there is a marked change in the case of the female as she then loses her tail-like appendage and swells up considerably. Fertilization takes place at that time and the fertilized female increases in breadth and resembles a pearly white flask or pear-shaped body (Fig. 10, F), losing almost altogether the worm-like appearance. The eggs hatch within the tissue of the root knot.

Control. Root knot of onions is especially serious when the onion crop follows a susceptible plant such as the tomato, cantaloupe, or black-eyed peas. It is very inadvisable to grow onions too long on the same land when the disease once gains a foothold. The only method of control known is to starve out the parasite in the soil. This is accomplished by adopting a system of rotation in which onions or other susceptible crops are omitted. The following crops may be classed according to their susceptibility to root knot. This list is here given with the object of aiding the onion grower to arrange his system of rotation.

Crops most susceptible to root knot: Onions, tomatoes, watermelons, cucumbers, squash, okra, egg-plants, lettuce, Irish potatoes, salsify, tobacco, cowpeas, burr clover, celery, carrot, cantaloupe, beet, cabbage, sweet potato, spinach, all varieties of soy bean, except Laredo, and lima bean.

Crops lightly attacked by root knot: Alfalfa (hairy Peruvian), asparagus, snap bean, sugarcane, sweet clover, collards, common vetch, strawberries, radish, garden peas, and cotton.

Crops mostly or entirely immune to root knot: Wheat, sorghum, rye, milo, nearly all the millets, nearly all the grasses, kafir, winter oats, cowpeas of the varieties, Iron, Brabham, Monetta and Victor, corn, velvet bean, Laredo variety of soy bean, and barley.

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THRIPS

Thrips tabaci Lind.

Historical. The onion thrips were introduced from Europe in 1872. However, its spread was very slow until 1907, when it suddenly appeared all over the United States. At present, it is found in practically every part of North America wherever onions are grown. Furthermore, it is found in other regions, from the Atlantic to the Pacific, and from Canada to Mexico. It is very prevalent in the West Indies and the Bermudas. To-day it occasions heavy damage in Indiana, New York, New Jersey, Maryland, Virginia, Colorado, Texas, California, New Mexico, Louisiana, Tennessee, Mississippi, Connecticut, Ohio, Idaho, Illinois, Michigan, Pennsylvania, Florida, North Carolina, Arkansas, Iowa, Washington, and Oregon.

Mode of injury. The thrips, incorrectly called onion louse, is a minute insect of microscopic size. The injury (Fig. 13, I and M) which it inflicts on the onion is variously named in the different parts of the United States. In some sections the injury is generally referred to as white blast, white blight, or silver top. As a result of this injury, "scallions" and "thick necks" (Fig. 13, K) are formed. These are undeveloped and unmarketable bulbs. In its worst form, thrip injury often invades entire onion regions, rendering the crop unprofitable and frequently destroying it. As the pest feeds on the onion plant, the leaves become whitened on account of the extraction of the plant juices. It does not take very long for the leaves to become characteristically whitened; they then become crinkled and twisted, and finally die prematurely. As a result of thrip injury, the upper halves of the foliage frequently shrivel and dry, giving the impression of a blight, which, in fact, is mistaken sometimes by people for the true blight or downy mildew, *Peronospora schleideniana.*

Food Plants. The reason onion thrips are so injurious is because the pest has a wide range of hosts. Besides feeding on onions, garlic, and related plants, the onion thrip also attacks cabbage, cauliflower, parsley, cucumbers, melons, pumpkins, squash, kale, turnip, tomato, lettuce, beets, beans, peas, celery, cotton, alfalfa, blackberry, strawberry, and practically every vegetable and truck crop, such as the potato and sweet potato. Mustard seems to be seldom severely injured. It also

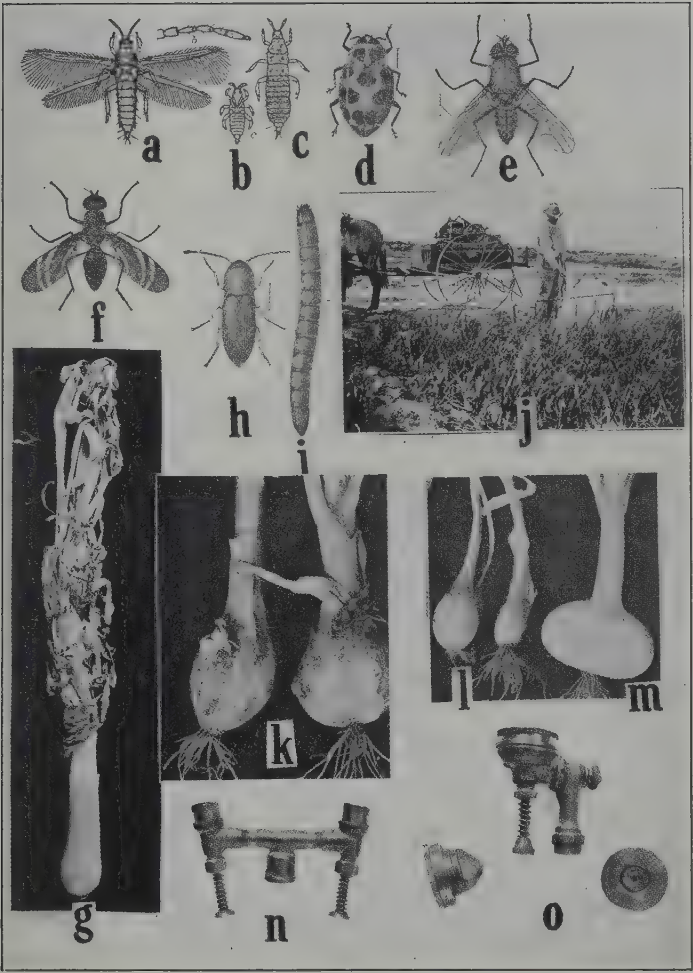

FIG. 13.

a. Adult onion thrip. *b*. and *c*. Small larva and nymph. *d*. Spotted lady beetle. *e*. Onion maggot, male fly. *f*. Black onion fly. *g*. Onion plant injured at the roots by wire worm. *h*. Adult of wire worm. *i*. Wire worm in larval stage. *j*. Power sprayer in operation against onion thrips. *k*. "Thick necks" resulting from thrip injury. *l*. Undersized onions due to thrip injury. *m*. Normal matured bulb not injured by thrip, same age as *l*. *n* and *o*. Types of nozzles used in spraying onions. (*a* to *o* after F. H. Chittenden.)

attacks ornamental plants, such as roses and carnations, in the greenhouse, frequently destroying entire beds. Greenhouse cucumbers are especially subject to its attacks. The tomato blossom drop, it is frequently claimed, is due to the injury from onion thrips. Quite often tobacco fields are ruined by thrips, but apparently not in America. Common weeds, such as dandelion, daisy, catnip, ragweed, goldenrod, aster, smart weed, and numerous wild grasses, serve as breeding places for thrips.

Onion thrips appear in practically every cultivated field, as well as in uncultivated areas where suitable food plants are found. For this reason onions are never safe from attacks of thrips, whether grown on new land or old land. In some localities, however, the previous crop seems to make little difference as to infestations, but, for the country at large, it is reasonable to suppose that the greatest infestation to onion fields will be found where crop rotation is not practiced, and where onions have followed onions, or such other crops generally favored by thrips.

Life History. The adult thrips, when not numerous, are usually found in the bud and appear on the leaves only when they multiply to great numbers. On plants other than the onion, thrips may be found imbedded deep in the flowers or usually on the lower side of the leaves.

It seems that the greatest damage is done by the female (Fig. 13, A). The female thrip by means of a tiny saw-like organ provided near the end of the abdomen is able to puncture the leaf or stem, making a considerable split into which she deposits her eggs. Here the eggs hatch in a few days and the young thrips (Fig. 13, B and C) work their way out and begin to feed at once. The young feed, as already stated, by sucking the plant juices in the same manner as the adults. Feeding is continuous, which means rapid growth and development of the young thrips. After a week or two, the length of time depending on temperature, they cease feeding, look around for some favorable location where they come to rest, and transform themselves to the third stage or the nymph, and later from that stage to the adult. Under favorable, that is, warm temperatures, it takes about three weeks from the time the eggs are laid until the mature adult is developed. For this reason it is not uncommon for half a dozen generations, or more, to be produced in one season. This is especially true in Texas, in many parts of the South, and in other semi-tropical countries.

CONTROL METHODS

Natural Control. Every onion grower has noticed that rains, especially heavy driving storms, help to destroy large numbers of the thrips. This is done by knocking them down to the ground, and they do not seem able to crawl up again, usually dying from drowning. Lady beetles (Fig. 13, D), especially the spotted lady beetle (*Megilla maculata* DeG.) and the convergent lady beetle (*Hippodamia convergens* Guer.) feed on large numbers of thrips. Another insect known as the flower-bug (*Triphleps insidiosus* Say) also helps to destroy large numbers of thrips. Finally, there are numerous internal parasites which help to kill off large quantities of the thrips. These parasites are quite common during moist weather.

Clean Culture. Since the onion thrips is able to feed on a large number of plants, it is imperative that soon after harvesting all unmarketable bulbs, as well as useless material such as "scallions," culls, tops, and "thicknecks," should be destroyed by being plowed under deep. This will bury and kill the thrip and prevent it from spreading to neighboring fields or crops. Furthermore, the onion field should never be near to cabbage, cauliflower, cucumber, and other similar crops. Whenever any crop is removed from the field, all refuse should be immediately plowed under and disced. The turn-rows and margins of the field should likewise be cultivated and kept free from weeds, which often act as carriers of the thrips.

In Texas where the main crop is produced from green sets, it is imperative that these sets be dipped before being put out in the main field; otherwise such sets may carry large numbers of the thrips from the seed-bed to the field. Considerable injury may, therefore, be prevented by dipping the sets when pulled and ready for transplanting in nicotine sulphate, the strength being the same as that used for spraying in the field (see page 230).

Any stimulation of growth which would be conducive to rapid bulbing and maturity will avoid that much injury from thrips. Manure or other fertilizer should be used freely to stimulate early growth. The growth is often stimulated by irrigation, cultivation, and the application of quickly-acting nitrogenous fertilizer (see page 197). Vigorous growing plants always stand a better chance of resisting attacks of thrips and making a marketable bulb.

Thrips may be controlled by spraying with a solution of soap and Black Leaf 40. In this connection, there are a few important points to impress upon the grower who is prepared to spray. The water used must be thoroughly saponified. River water or well water is likely to be hard and requires to be neutralized. The amount of soap required depends upon the character of the water. Enough of the soap should be dissolved so that the solution will not become flocculent when cooling. To make sure that the soap and the water will remain well mixed only a quart of soap suds at one time should be added, stirring and gradually adding the balance of the suds. By constant stirring the water will be saponified without flocculating. The suds are made by dissolving three or four pounds of any good laundry soap in three or four gallons of boiling water. A 50-gallon barrel is filled with about 45 gallons of water to which the three or four gallons of soap suds are added gradually as indicated above. More water is added to make 50 gallons. To each 50 gallons of saponified water add five or six ounces of sulphate of nicotine, popularly called B. L. 40 (Black Leaf 40). This is well mixed, and the solution is ready for use. It can not be too strongly urged that the water and soap solutions should be well balanced, because the even spreading of the film of spray on the leaves is absolutely essential. Perhaps the best way to test whether or not the mixture has enough soap is to see if the spray draws together in drops and leaves part of the foliage dry. When this is the case, more soap should be added. It should, of course, be remembered in this connection that it is the soap which helps the nicotine sulphate solution to adhere to the foliage. In preparing nicotine sulphate on a large scale—say, to treat plants for about thirty acres by dipping the green sets before planting—one ten-pound can of Black Leak 40 is dissolved in 1000 gallons of water in which has been dissolved fifty to sixty pounds of ordinary soap. This is prepared in large galvanized tin tanks, in which the sets are suspended for one hour, after which time they are ready for immediate planting. If the liquid has stood for any length of time, it is still good for use, but it should be well agitated. Spraying (Fig. 13, J) is effective only if the thrips actually receive a coating of the nicotine sulphate solution. Spraying is done only when the insects make their appearance, and should be continued at intervals of three to seven days and cease about two to three weeks before harvest. Market prospects sometimes help to decide whether or not spraying will pay. As it happened in the season of 1921, the onion crop of Texas was badly attacked by thrips shortly before harvest. However, no attempts were made by the Texas growers to spray, simply because market conditions were badly demoralized and it would not have paid them to invest money and labor in spraying. However, under normal conditions, spraying to control thrips is imperative, as it is practically the only means of insuring a crop. Occasionally, fish-oil soap may be used instead of Black Leaf 40 or nicotine sulphate, but it is more expensive and is apt to burn the plants. For ordinary everyday purposes, therefore, the nicotine sulphate is to be depended upon. Occasionally, when the attack of thrips is very severe, there may be instances of leaf burning unless neutral or mild soap is used. In this case the epidermis or outer skin of the foliage has been so badly injured by thrips that, if the soap is not mild or neutral, it certainly will cause burning.

The kind of spraying machinery will depend on the locality. For instance, an apparatus suitable under irrigation conditions in Texas will be unsuitable for similar work in the bog-lands of Indiana and Michigan. The success in spraying depends not so much on the type of sprayer used as on the amount of power it has and the kind of nozzles used. Any machine with 150 pounds pressure, or more, will answer the purpose. The best type of nozzle is the Vermorel (Fig. 13, N and O).

In the bog-lands of Indiana and Michigan, special spray machines are used in which strips eighty feet wide may be sprayed at one time with one machine. This sprayer derives its power from the gasoline engine which supplies liquid through two pipe booms and the nozzle clusters are provided with three or four disc type nozzles. Each boom section of pipe which is attached to the sprayer tank is supported by guide wires, and can swing through an angle of 180 degrees by means of a pivot union which is attached at the front. This is placed at such a height as to clear a man's head without difficulty. This is necessary so that it may not hinder the operator; neither should it be too long, as it may become twisted out of shape through strain. Ordinarily, about twenty feet should be sufficient. The hose connection from the end of this boom should be from ten to fifteen feet long and attached to a ten-foot spray rod. This will afford a spraying radius of forty feet on one side of the tank and, since there are two such arrangements, the machine will cover an area of eighty feet.

Dusting with Nicotine Sulphate, Nico-Dust. It has been stated above that onion thrips may be readily controlled by spraying with nicotine sulphate and soap solution. From the standpoint of killing-efficiency, the solution is very desirable. There are, however, drawbacks to its use, the following of which may be mentioned. The onions, as they are usually planted in the main field, are put out in rows twelve or fourteen inches apart in long beds of various dimensions. The irrigating canals and laterals cross the field about every 600 feet. On account of the closeness of the rows and the irrigating laterals which cross the fields, the operation of horse-drawn spraying machines may cause damage to the plants through tramping or in breaking the sides of the beds. Cultural work on onions is generally carried on by means of burros or ponies having small feet. But the average spray machine requires larger animals, thereby causing still further damage to the plants. In using the nicotine sulphate dust one may even use, on a commercial scale, an ordinary hand-operated bellows duster so that one man can easily cover from one and one-half to three acres per day, using about twenty pounds per acre; averaging $3.00 to $3.50 per acre, including labor and material. It is possible to use a small-power operating duster which is so arranged that eight rows may be covered at one time with one pipe discharging directly over each row. With this outfit one can cover twelve to twenty acres per day, using twenty to twenty-five pounds of dust per acre at a total cost of $3.00 to $4.00 per acre, including material, labor, and the hire of a pony or a mule.

Field tests by the authors in the Texas Laredo Bermuda onion districts developed many practical points in connection with the successful use and application of the Nico-dust.

Various formulas were tried in which Nico-dust was combined with sulphur, fuller's earth, and hydrated lime. So far as Bermuda onions are concerned, it matters little which of these are used as fillers, so long as the strength of the nicotine sulphate is maintained. In case it is desired to dust cantaloupes and cucumbers against the melon aphis, it is important to avoid the use of sulphur to prevent the burning of the foliage.

The very young and newly-hatched thrips, and all the larval forms preceding the pupa or wing-pad stage, are easily killed by five per cent Nico-dust. This means that either fuller's earth or hydrated lime, or proper combination of the two, contains at least five per cent Black Leaf 40, which would be two per cent actual free nicotine.

For the pupal or wing-padded stage, it has been found that at least a seven per cent Nico-dust, equivalent to 2.8 per cent free nicotine content, is necessary to be effective. However, for the adults this strength is found to be too slow in securing the best results. The most efficient and quickest killing effect on all stages, including the adults, is secured by a ten per cent Nico-dust, which is equivalent to a four per cent free nicotine content. With this strength all the larval forms are killed almost instantly, the pupal forms very quickly, and the adults as soon as their bodies are actually covered by the dust. However, the ten per cent strength of Nico-dust is rather expensive and is justified for extensive use only in the seed-beds and under extremely critical field conditions. For seed-bed treatment two applications given at about three- to four-day intervals will be effective. Dusting should be done during bright, sunshiny calm days.

For field dusting, the following factors should be seriously considered in the use of the Nico-dust to control onion thrips.

1. The prospects of high prices when the crop matures. If these are sufficiently attractive, the more ex-

pensive formulas may be used with the greatest profit, because they have the greatest killing effect.

2. The stage of maturity of the crop. If the attack of the thrips comes late when the crop is nearly made, the grower may not get value received for cost of materials and labor.

3. The price of onions being only average, or probably below the average, the grower is justified in using a 7 per cent Nico-dust to combat an early attack of thrips in the field. The liberal use of this formula will control the pest to the greatest extent with the least average cost when considered in relation to the increased yield and average price.

It is important to observe in this connection that an infestation of thrips often appears in small spots in different portions of the field. In this case, the pest may be checked by two to three dustings with 10 per cent Nico-dust. By eradicating these early-breeding centers we may save the necessity and the expense of dusting the entire field.

Dusting Machines and Nico-dust Factories. There are several factories in New York and California which have worked out methods of making the most stable Nico-dust preparation. Other factories located in the same town, or in close cooperation with the dust factories, are making high-class dusting machinery. The machine may be of small size to be applied by hand labor, or larger size to be operated by horse power.

OTHER INSECT PESTS OF THE ONION

Maggots. Of the root maggots (Fig. 13, E and F), may be mentioned the seed-corn maggot (*Pegomya* *fusciceps* Zett.) and the imported onion maggot (*Pegomya cepetorum* Meade). The seed-corn maggot is so named because it is known to attack sprouting seed-corn. It also feeds on various other crops, among which is the onion. This insect has been introduced from Europe and it is now distributed from Maine to Washington and southward. The adult of this pest resembles the common house-fly. In its earlier stages, the maggot is footless, pale yellow to white, and feeds on the interior of the bulb.

The imported onion maggot is equally troublesome, as it feeds on the bulb, resulting in subsequent decay. Both the flies and the maggot of this species resemble the seed-corn maggot somewhat and can only be distinguished by a careful microscopic examination.

There are also other pests, one of which is known as the black onion fly (*Tretoxa flexa* Wied.). Both of these pests are very troublesome to the onion crop. As soon as the maggots of these flies hatch, they confine themselves under the sheath and feed on the juices of the plant. In this case the outer leaves become brown, seared, and finally withered. The fact that hibernation of the pupæ of these two pests takes place inside the onion makes it imperative to destroy in the fall all onions which show infection; whereas, the sound ones should be disinfected with bisulphide of carbon. For all forms of root maggots the method of control recommended is the use of carbolized form of kerosene emulsion. To one pound of soap which is boiled in one gallon of water, one-half gallon of crude carbolic is added and the whole is then diluted with thirty-five to fifty gallons of water. This mixture is thoroughly stirred and sprayed at the base of the plants in seed bed rows. It is advisable to apply this one or two days after the plants are up, or after transplanting. This application is repeated every ten days for three or four applications.

In the application of fertilizer all fresh manure should be avoided. The same is true for cotton-seed meal and any form of organic matter. The odor of decaying organic matter attracts the female to lay her eggs there. For this reason chemical fertilizers are recommended.

Cut Worms. Heavy losses are frequently entailed from cut worms. These are well known and require little description. There are several species of these cut worms, some of which may be mentioned: *Euxoa punctigera* Walk., *Euxoa tessellata* Harr., *Euxoa messoria* Harr. Another important species may be mentioned, the variegated cut worm *Peridroma nargaritosa* Haw. All these worms injure the plant by cutting it off at the foot. The usual method of controlling cut worms is by using poisoned bait made up as follows: To one bushel of bran is added one pound of arsenic or paris green; this to be thoroughly mixed and made into a mash with eight gallons of water to which has been added and stirred in one-half gallon of sorghum or other cheap molasses. The juices and finely ground pulp of a half dozen oranges or lemons should be added to the water and well stirred before adding to the molasses. After being thoroughly mixed, the mash is allowed to stand for several hours and is then sown broadcast in lumps not larger than a marble, in various parts of the field where the injury is noticeable. Occasionally, one application kills out all the worms. At other times, however, a second application is desirable.

In addition, clean culture and crop rotation are advisable, as well as fall plowing and discing.

Wire Worms. In addition to cut worms, wire worms are frequently injurious to onions (Fig. 13, G). These are elongated, wirelike worms and are really the larvae of click beetles (Fig. 13, H and I). Perhaps the only way to control this pest is clean culture and crop-rotation. By clean culture the adults are compelled to seek shelter outside of the onion fields. In this way they become exposed to the attacks of natural enemies and birds, which destroy many of them.

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GLOSSARY

A

Acervulus. A small group of fungus tufts on which are borne fungus spores.

Antheridium. The male sexual organ in fungi.

Apical. At the point of any structure.

Ascospores. Spores formed in an ascus.

Asexual. Without male or female organs.

B

Bulbils. Aerial, deciduous, fleshy leaf buds, capable of developing into a new individual as in the Egyptian and Multiplier onions.

Bulblets. Bulbils.

C

Chlamydospores. Resting spores with very thick walls formed within mycelial cells.

Conidia. Spores formed asexually.

Conidiophore. A spore-bearing fungus stalk.

Crozier. A growth resembling a circinate or coiled young fern frond.

Cuticle. The outermost skin of plants.

D

Dehydrator. An implement used to drive out excess water of vegetables or fruits.

E

Entomogenous. Living on insects.

Enzyme. An organic chemical product capable of bringing about chemical changes but without itself undergoing any change or entering into the final product.

F

Flagellae. Whip-like appendages of protoplasm of bacteria and swarm spores.

Flagellate. Provided with flagellae.

Fungus. A plant of very low order. Its mycelium corresponds to roots of higher plants and it reproduces by means of spores.

G

Gamete. A protoplasmic sexual body.

Guttulate. Drop-like.

H

Haustoria. Special organs of a fungus which are used for attachment or for obtaining food.

Host. Any plant which nourishes a parasite.

Hyaline. Translucent or colorless.

Hyphae. Thread-like vegetative part of a fungus.

I

Infect. To communicate disease.

Intercalary. Growth which occurs between the tip and the base.

Intercellular. Growing between the host cells.

Intracellular. Growing inside the host cells.

L

Lesions. Definite diseased areas.

M

Macroconidia. Large conidia.

Membranaceous, Membranous. Thin and semi-transparent.

Micro. Small, little.

Microconidia. Very small conidia.

Mycelium. Vegetative threads or hyphae of a fungus.

O

Omnivorous. Attacking a large variety of plants.

Oogonium. Female sexual organ of fungi containing one or more oospheres.

Oosphere. A naked mass of protoplasm developing into oospores after fertilization.

Oospore. Fertilized oosphere.

P

Parasite. Any organism living at the expense of another (the host).

Pathogene. A disease-producing organism.

Pedicel. A support.

Perithecia. Flask-shaped, globose, sexual fruiting bodies containing asci.

Peritrichiate. Possessing flagellae all over the surface.

Pionnotes. An effuse conidial stage containing a maximum of conidia and a minimum of aerial mycelium.

Pseudo-spore. A false spore.

Pustule. A blister or pimple.

Pycnidium. A sac-shaped fruiting body of a fungus in which the pycniospores or summer spores are formed.

Pycniospores. Summer spores of certain fungi which are formed in a pycnidium.

S

Scallion. Any onion that develops no bulb but has a long thick neck.

Sclerotia. Compact masses of mycelium in a dormant state. These bodies help to carry the fungus over unfavorable weather conditions.

Septate. Divided; a partition between two cells in the same fungus thread.

Spathe. A large bract, frequently colored, or a pair of bracts sheathing a flower cluster, especially a spadix.

Spore. A seed body of bacteria or fungi.

Sporidia. Minute spores. Term applied to spores produced on promycelia.

Sporodochia. Broom-shaped sporiferous apparatus in the genus Fusarium.

Sterigma. A stalk-like branch of spores bearing basidium.

T

Tapering. Growing small by degrees toward one end or in one direction.

INDEX

A

Allium cepa, 3, 169.
—— —— bulbellifera, 164.
—— magicum, 136.
Ammonium sulphate, 41.
Anderson, P. J., 163.
Animal Pests, 223.
Anthracnose, 131.
Artificial drying, 134.
Aspergillus niger, 165-167, 181.

B

Bacillus carotovorus, 119, 120, 166, 181.
Bastard blossom, 115.
Bermuda, white, 48.
Bessey, E. A., 225.
Black Leaf 40, 229.
—— mold, 165.
—— onion fly, 236.
—— spot, 131.
Blight, 117.
Bordeaux mixture, 125.
—— preparation, 127.
—— stock solutions, 127.
Borders, 26.
Border system, 31.
Botrytis allii, 169, 172-174, 201, 202.
—— *cana*, 173.
—— *destructor*, 123.
Bottom sets, 74.
Bulblet head, 115.
Bunching onion, 18.
Byars, L. P., 225.

C

Campbell, R. E., 238.
Canary Islands, 48.
Celery hiller, 27.
Chittenden, F. H., 238.
Cleaning, 82.
Cleisthothecopsis circinans, 131.
Climatic requirements, 6.
Clinton, G. P., 115, 118, 164, 177.
Clipping, 81.
Colletotrichum circinans, 133.
Containers, 91.
Cooke, M. C., 162.
Coons, L. H., 222.
Cotton, A. D., 203.
Cotton Seed Meal, 42.
Cover crops, 24, 36.
Cracking, 118.
Crating, 82.
Creole onions, 17.
Crop rotation, 45.
Crusting, 53.
Crystal wax onion, 48, 78.
Cultivation, 64.
—— horse, 30, 65.
Curing, 77.
Cut worms, 237.

D

Deep tillage, 24.
Dehydrator, 97.
Diseases in transit, 213.
Distribution, U. S., 4.
—— World, 4.
Ditches, 26.
Dodder, 205.
Double flower, 115.
Doubles, 74.
Downy mildew, 117, 121.
Drill, gang, 56.
—— hand, 56.

Dry farming, 66, 68.
—— kiln, 97.
—— sets, 73.
—— —— production, 110.
Dudley, 129.
Dusting machines, 235.

E

Economic importance, 8.
Edgerton, C. W., 118.
Elongated spathe, 116.

F

False blight, 117.
Farlow, W. G., 162.
Fertilizer, 33.
—— commercial, 37.
—— formulae, 44.
Fertilizing old lands, 43.
—— virgin soils, 43.
Fish oil soap, 231.
Flat bed, 31.
Flower bug, 228.
Formaldehyde drip method, 147.
Fungi parasitic on Allium, 203.
Furrows, 29.
Fusarium malli, 179.
—— *oxysporium*, 194.
—— rot, 199.

G

Garlic, 18.
Gilbert, W. W., 225.
Goff, E. S., 130.
Gooseneck, 116.
Grade determination, 26.
—— leveling, 25.
Grades, U. S., 88-91.
Grading, 85.
Green bunching, 74.
Greening, 55.
Green, W. J., 162.
Guano, bat, 41.

H

Hail injury, 116.
Halsted, B. D., 162.
Harding, H. A., 120.
Hardpan, 24.
Harvesting, 77, 81.
Head of water, 27, 59.
Heterodera radicicola, 223.
Historical, 3.
Humus, 33.

I

Implements, 103.
Insect pests, 223.
Irrigation, 59, 80.
—— furrow, 30.
—— overhead system, 62.
—— water, 60.

J

Jones, L. R., 120, 130, 163.

K

Kirk, T. W., 130.

L

Lady beetles, 228.
Leaf mold, 177.
Leek, 18.
Liliaceae, 3.
Lime, 39.
Loading cars, 94.
Location, 20.

M

MaCaun, W. T., 130.
Macrosporium parasiticum, 118.
—— *porri*, 118, 177, 205.
—— *sarcinula*, 177, 178.
—— —— var. *parasiticum*, 177.
—— *solani*, 177, 178.
Mally, F. W., 199.
Manure, 35.
—— stable, 107.
Marketing, 92.
Markets, 92.
Martin grader, 28.
Maxime Cornu, 162.

Morse, W. J., 120.
Muck lands, 19, 79.
Munn, M. T., 176.

N

Neck rot, 169.
Nelson, Ray, 222.
Nico-dust, 232.
Nicotine sulphate, 232.
Nitrate of soda, 40.
Nye, T. C., 4.

O

Onion brittle, 117.
Onion maggots, 235.
Onions, dried, 97.
Owen, M. N., 203.

P

Pammel, L. H., 162.
Peronospora schleideniana, 117, 121-123, 177, 178, 205, 226.
—— *schleidini*, 123.
Phosphate, 39.
Pink root, 179.
Plant Disease Bulletin, 138.
—— —— Survey, 170.
Plow sole, 24.
Potash, muriate, 40.
—— sulphate, 40.
Production, cost, 101.
Puccinia porri, 164.

R

Refrigerator cars, 95.
Root knot, 223.
—— system, 57.
Rows, bedded, 30.
Rust, 164.

S

Sclerotinia libertiana, 164.
—— *bulborum*, 173.
—— *cepae*, 173.
—— *cepivorum*, 173, 201, 202.
Seed-beds, 49.
Seed-bed cultivation, 53.
—— preparation, 50.
Seed, Bermuda onion, 48.
—— care, 109.
—— production, home, 105.
—— sowing, amount, 51.
—— —— depth, 52.
Seed-testing, 47.
Selby, A. D., 135.
Sheep shears, 81.
Shuffling, 82.
Smudge, 131.
Smut, 136.
Soap, resin fish oil, 128.
Soft rot, 119.
Soil preparation, 23.
—— requirements, 19.
Sowing, time of, 50.
Splits, 74.
Splitting, 118.
Spores on onion seed, 204.
Stevens, F. L., 135.
Stone, A. L., 207.
—— G. E., 162.
Storage, 78, 99.
—— storage houses, 211.
—— rots, 208.
Sturgis, W. C., 162.

T

Tankage, 42.
Taubenhaus, J. J., 168, 199.
Thaxter, R., 130, 135, 162, 178.
Thrips, 225.
Tools, 103.
Transplanting, 54.
—— advantages, 53.
Tree onion, 18.
Trelease, W. M., 130.

U

Urocystis anemones, 160.
—— *cepulae*, 136, 137, 144, 147, 148, 160, 205.
—— *colchici*, 136, 137.
—— —— var. *cepulae*, 137.
—— *magica*, 136.
—— *violae*, 160.

V

Varieties, 16.
Vermicularia circinans, 133.
Voglino, L. E., 203.
Volutella circinans, 131.
—— *fructi,* 133.

W

Walker, J. C., 135, 163, 178, 207, 222.
Ware, B. P., 162.
Water, head, 27.
Watery soft rot, 164.
Watts, R. L., 162.
Wayne, Van Pelt, 168.
Whetzel, H. H., 129.
White mold, 201.
—— ring, 116.
—— spot, 118.
Wire worms, 237.

Y

Yellow leg, 200.

F

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